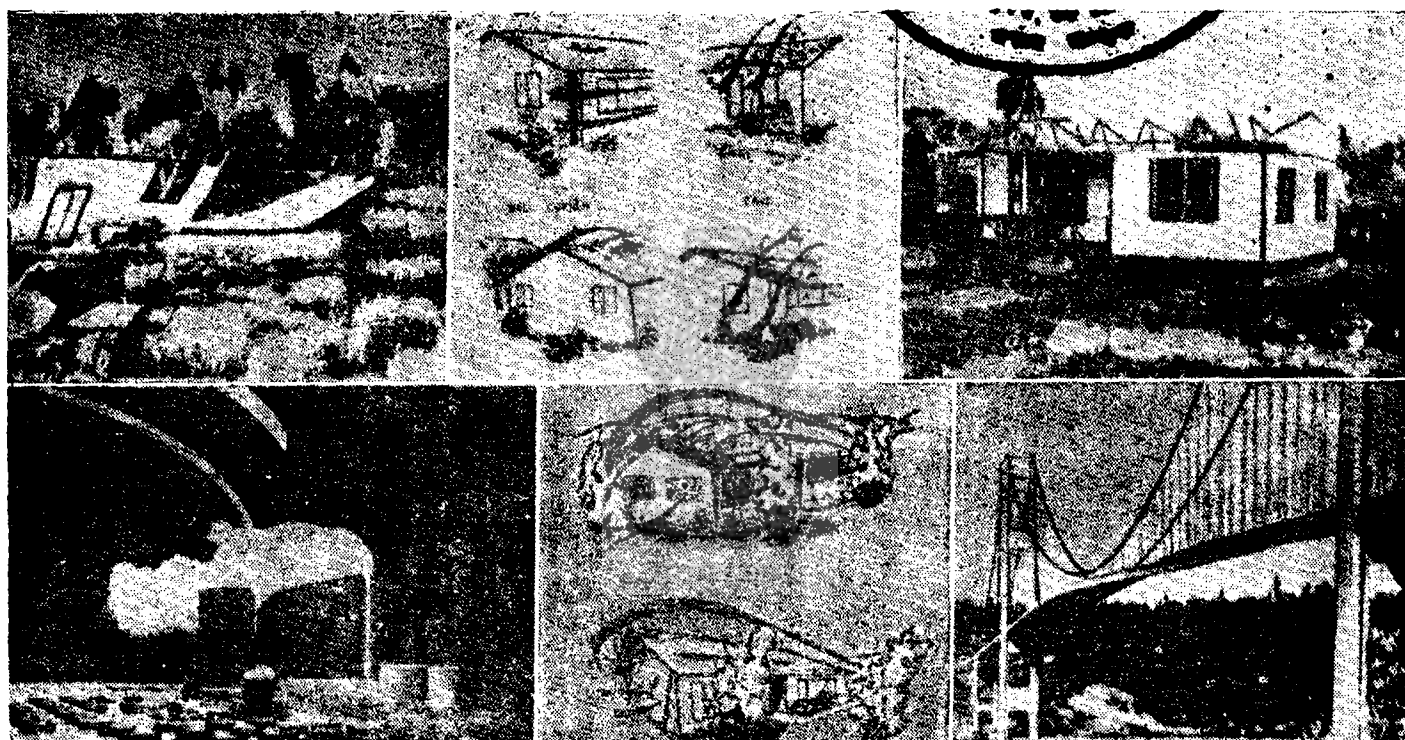


REPORT OF THE COMMITTEE ON WIND ENGINEERING

DECEMBER 1982



Government of India
Department of Science & Technology
Technology Bhawan New Mehrauli Road,
NEW DELHI-110016

Printed by : LOVELY OFFSET WORKS, PAHARGANJ, NEW DELHI-110055 Ph. : 513803



P R E F A C E

Wind storms of varying intensity occur in the Indian subcontinent, with awesome regularity, resulting in a loss of thousands of human and other lives and property worth hundreds of crores of rupees. So far a very limited effort has been made in the affected countries generally and in India particularly to understand the nature of forces unleashed by storms and their effects. Unless this work is taken up in right earnest, very little can be achieved by way of mitigating the disastrous results that follow from direct losses and consequent disruption in economic and social life of the affected region. In recognition of such a need, the Department of Science and Technology had set up a Committee on Wind Engineering to assess, in a broad sense but particularly in India, the state of the art in terms of the capabilities for the measurement of wind speeds, facilities to study the response of structural models and proto-types, provisions in the existing Indian Standards to enable the preparation of safe designs, and, disaster mitigation or relief preparedness. The committee has made a comprehensive study of the problem and has made its recommendations, based on available information and expert opinion.

In short, the recommendations of the Committee include the steps required to place the task of wind measurements and other data collection, instrumentation, development of facilities for R & D work, standardisation and education, dissemination of information and interaction with international agencies, on a proper footing. It is envisaged that preparations to take up the various projects involved will be possible within the 6th plan period and the projects can be pursued effectively during the 7th plan period. The estimated outlay for this work over a period of five years is Rs. 2.55 crores. A further review of the matter needs to be made during the 7th plan period to assess the progress made and future needs for Wind Engineering studies.

Jai Krishna

(JAI KRISHNA)

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1. SUMMARY AND RECOMMENDATIONS

The Indo-US workshop on Natural Disaster (Earthquake and Wind) Mitigation Research was sponsored by the Department of Science and Technology and was held from Dec. 13-16, 1978. One of the topics discussed related to Wind Effects on Structures. It was noted that due to extreme wind conditions, there is loss of life and property in India almost every year, but no coordinated research in the area of Wind Engineering has been formally organised, excepting for Aeronautical purposes. The workshop, therefore, identified the following projects for research and collaboration:

1. Measurement of Wind Speeds in Intense Tropical Storms.

Design and development of rugged and reliable anemometer for measurement of high wind speeds, including setting up of an experimental network in the east coast of India for measuring basic parameters of extreme wind and correlation with mathematical models.

2. Risk Analysis and Preparation of Wind Zoning Maps.

Risk analysis based on available wind data for the preparation of zoning maps and recommendations for codes and standards.

3. Experimental Study of Wind Effects on Structures

Study of wind effects on structures through instrumentation and observations on models and prototype structures.

In addition to the above, the workshop recommended, that there should be an exchange of research workers and literature between the two countries in the area of Wind Engineering. It was also recommended that a Committee at the national level be appointed in India to draw up plans for comprehensive research in this field. As a follow up of the above recommendation, a committee on Wind Engineering was constituted by the department of Science and Technology.

The composition and terms of reference of the committee are as follows :

COMPOSITION

- | | |
|---|-----------------|
| 1. Prof.Jai Krishna, professor Emeritus,
Roorkee University, Roorkee. | Chairman |
| 2. Dr. P.K.Das, Director General,
Meteorology, IMD (or his rep.) | Member |
| 3. Shri G.Raman, Director, Civil Engineering
Indian Standards Institution, New Delhi | " |
| 4. Shri G.C.Mathur, Director, National
Building Organisation, New Delhi | " |
| 5. Dr.B.Venkateswarlu,Structural Engineering
Research Centre, Madras | " |
| 6. Prof. G.N.V. Rao, Indian Institute of
Science, Bangalore | " |
| 7. Prof. Prem Krishna, Roorkee University | " |
| 8. Dr. N.C.Nigam, Indian Institute of
Technology, Kanpur | " |
| 9. Prof. B.Basu, Indian Institute of
Technology, Kharagpur | " |
| 10. Dr. D.K.Rakshit, Department of Science &
Technology. | Member Secretar |

TERMS OF REFERENCE

- i) To review present status of wind observation, their use in code provision for design of structures and to quantify losses involved at present.
- ii) To identify R and D programmes for the design and development of proper equipment to measure high wind and estimate wind force and equipment for observation of strain in existing structures due to wind force. Also the optimum number of equipment required under each category may be projected.
- iii) To identify research programmes for understanding the behaviour of tall structures, light bridges and roofs due to wind force including aspects involving resonance phenomena.
- iv) To suggest change in the code provision for making design of structures more efficient.
- v) To recommend measures for promoting education of engineers on wind engineering problems.

- vi) To Liaise with other national and international agencies dealing with wind engineering problems particularly on wind effect mitigation.

The committee held four meetings on December 27, 1980 September 21, 1981, January 14, 1982 and December 29, 1982. As many as 20 documents prepared by the members (List given at Annexure A₁) were considered by the Committee. The minutes of the above meetings are at annexure A₂.

The committee, after considering the various documents, identified a serious lack of observation and research facilities for collection of necessary data to design engineering structures against wind forces. Almost every year many buildings, electrical transmission towers, and other tall structures suffer damage and upset the power and communication facilities affecting production besides loss of life. The committee also noted that there was no formal arrangement to train manpower for either field observations or research or design.

Details of the deliberations of the committee are given in Sections 2 to 6 of this report, while the recommendations are given as follows :

1. Since the present teaching of Wind Forces is based on rules and practices, formal arrangement for giving scientific education to engineers on wind effects on engineering structures be made since future industrialisation will mean more tall buildings and industrial structures besides power and communication systems and the need for safeguarding them against failure will be felt more and more. It is recommended that the Ministry of Education and UGC may be advised to take necessary steps to get an optional subject 'Wind and Its Effects on Structures' introduced in the engineering curricula of the leading institutions so that, in due course, trained manpower is available for observation, research and design purposes. Support may be provided for short courses, workshops/ conferences to educate the people.
2. The present wind observations taken by the IMD consist of measurement of velocity at low heights (about 10m). There is a need to build observation towers and utilise existing tall towers, e.g. T.V. Towers, P & T Microwave and AIR towers, chimneys and buildings to obtain variations in wind along height, in various parts of the country. Four places namely, Madras, Balasore, New Delhi and Varanasi were identified for intensive observation on various parameters of wind in the 1st phase of establishing observation stations. A small committee may be appointed to prepare a detailed plan for these stations taking into account the existing facilities there, with I.M.D. as Convener, and scientists from SERC Madras, Institute of Science, Bangalore and University of Roorkee as members.

The committee is confident that installation of Wind measuring Instruments in the TV towers will not vitiate the performance of the towers.

One of the most important parameter to be observed is the variation of wind with time on a continuously recording system. The instruments presently available are not suited to measure the extreme wind speed and acceleration, which materially affect the behaviour of the engineering structures. It is therefore, recommended that suitable instruments be developed for the purpose. The broad specifications have been indicated by the committee. (Reference Annexure A₅ - Wind Data). The proposed instruments should be operative upto an altitude of 150m and wind velocity upto 300km/hr with wide range of recording frequencies. The Institute of Science, Bangalore and University of Roorkee have acquired expertise in developing and testing equipment of the type indicated above.

After the instruments have been developed, arrangements need be made to manufacture a good number of such instruments and install them at the predetermined locations. The routine maintenance, operation and data collection should be the responsibility of the IMD which is already maintaining a network of wind observing stations in the country for weather prediction purposes. However, the analysis of wind data collected at the above specified network of stations and their conversion to usable design information will primarily be carried out by the research workers of the institutions where research on the effect of wind forces on structures is being undertaken.

Since the ISI code on Wind forces is based on limited data, there is a need to collect more data and also organise research for determining wind coefficients for different kinds of engineering structures. The committee recommends that the ISI may update the present code as indicated by the above work from time to time. The Committee notes that ISI has taken up work in this direction.

In order to give adequate encouragement to research in the area of Wind Engineering, the wind tunnel facilities, namely, at the I.I.Sc. Bangalore and the University of Roorkee be augmented to provide for adequate range of wind speeds and instrumentation in order that the various types of Civil Engineering Structures can be tested. The wind tunnel project of IIT, Kanpur may be continued. Further, since it is expected that there will be a considerable demand on such facilities in future, the facilities provided should be well distributed from the regional point of view, and thus the setting up of a new wind tunnel facility at the I.I.T. Kharagpur is also recommended. Each of the organisations may submit projects and estimates for the consideration of the DST.

The Committee noted the on-going project of SERC, Madras on constructing a wind tunnel for cyclonic study. The Committee hopes that the funds required for it will be provided by the CSIR and has made no provision in the estimate submitted as part of this report.

As regards developing the right type of instruments for the wind tunnel the Committee recommended to import initially one or two suitable instruments from abroad and thereafter develop them in the country.

The Committee also felt that in the area of Wind Engineering, particularly as regards the wind tunnel design and instrumentation, much richer experience is available in countries such as USA, Canada, Australia and Japan and interaction of the Indian Researchers with them can be most fruitful. It would be useful to send a small team of research workers to the above countries to study this type of research on Engineering Structures in that country to take advantage of the experience already gained by them.

In addition to the facilities mentioned in (5) above the Committee considered the necessity of creating a large scale multi-purpose facility for testing of Civil Engineering Structures on a large enough scale to model the Reynold number values that occur in the field, and for tests on Aircrafts or Atmospheric flight vehicles. The cost of setting up such a facility is estimated to be Rs.10 crores and it is recommended that the DST may introduce the outlay of these funds in its future plans. For the present, it is necessary to concentrate on smaller tunnels to develop expertise and solve usual problems.

A standing committee may be appointed by the DST to plan and evaluate research projects on Wind Engineering and monitor the projects from time to time.

The composition of the Committee may be as follows :

1. An eminent engineer/scientist Chairman
2. Representatives of IMD, ISI, NTPC, NBO and CPWD
3. Representatives of I & B, Education, Science and Technology.
4. Representatives of University of Roorkee, IISc., Bangalore, IIT., Kharagpur and SERC., Madras.

The committee may set up a small committee to prepare specifications of the observation tower alongwith equipment required as a complete plan as mentioned in para 2 earlier.

Also in cases of wide-spread failure due to a wind storm, or, the failure of an important installation, a systematic study be carried out by a team of experts formed by the committee.

8. Damage documentation should be taken up on a comprehensive basis.

Based on work done in regard to common man's dwellings, the SERC Madras, may take up the task of preparing a monograph laying down specifications for the safe design of such dwellings.

IMD and SERC may arrange publication of relevant wind data of selected stations from different parts of the country every 3 months.

9. The actual requirements of funds will be known when different organisations submit detailed estimates for their part of work, but approximate projections are indicated below for a 5 year period 1983-88 :

<u>Items</u>	<u>Rupees in lakhs</u>
1. Development and acquisition of instruments and sensors	25
2. a) Strengthening of existing wind tunnel facilities at Bangalore, Roorkee and Kanpur	60
b) Installation of a new wind tunnel at I.I.T., Kharagpur	40
3. Cost of towers, instruments and their installation and maintenance	65
4. Specific Research Projects	50
5. Co-ordination activity	15
Total for 5 years ...	Rs.255 lakhs

2. BACKGROUND AND OBJECTIVES

Meteorological Department, Government of India, compiles based on press reports, data relating to the Disastrous weather events in the country annually which, inter alia, include information about losses to life, cattle, and property caused by (i) Cyclonic storms, (ii) Dust/Sand storms, (iii) Snow storms, (iv) Thunderstorms, (v) Hailstorms, (vi) Squalls and (vii) Gales.

According to the Disastrous Events Reports available for the year 1974 to 1978, 11, 751 human lives and thousands of cattle and birds were lost. Apart from this, severe losses are caused on account of disruption of water and electric supply as a result of damage to installations for these public utilities. Communications-road, rail and water (sea or river) are also very badly damaged owing to such natural events, in turn causing losses not only these systems as such e.g. damage to installations but also resultant adverse effects on trade, commerce and industry, giving rise to huge financial losses for those connected with it. A very rough estimate of direct loss in financial terms to the communications, installations and electricity and water supply system etc. based on these reports was Rs. 347.45 crores in five years (1974 to 1978). Besides this, huge losses also occur in terms of collapse of houses, razing of thousands of huts to the ground and other buildings, destruction of crops etc. on account of wind storms of the type mentioned above and also by floods caused by them. Thus wind storms not only cause misery to the human beings but also bring about loss in crores of rupees in the form of damage to the house and other property. Annexure A₃ gives a survey report on structural damage due to cyclone in Andhra Pradesh and annexure A₄ gives an account of measures being taken by various agencies for mitigating the adverse effects of high wind on common man's dwellings.

A concerted effort is needed to study the problems related to wind storms and their effects to attempt, reduction in such losses that occur repeatedly. From this point of view the Wind Engineering Committee has addressed itself to the task of assessing and examining the position of wind engineering studies in respect of the following aspects and made recommendations for further effort needed.

1. Assess present position regarding :
 - i) Observation of wind data in various parts of India.
 - ii) Code provisions for design of structures.
 - iii) Place of wind engineering in education of engineers.
2. Assess the present position and identify areas for further work in :
 - i) Estimation of wind forces.

- ii) Equipment required to make necessary observation of wind data.
 - iii) Design of equipment for observation of response of existing structures due to wind forces.
 - iv) Behaviour of tall structures and light weight bridges and roofs to revise their design procedure.
3. Suggest changes in Code provisions for making design of structures more efficient.
 4. Collaboration with U.S. Specialists in the field of wind engineering as a part of Indo-US collaboration programme, condition in the two countries being comparable.
 5. Liaison with international agencies dealing with Wind Engineering problems.

The subsequent part of this report is aimed at meeting the above objectives. The material is arranged from the view point of design engineers whose task is to produce structures and buildings with adequate safety under wind loads.

The spectrum of wind engineering problem from the view-point of design of structures divides itself into three clear areas :

1. Analytical study of structural response-theoretical and experimental on both wind tunnel models and prototypes.
2. Collection of wind data and determination of its direct and indirect effects on structures of various forms.
3. Preparation of updated wind zoning maps and codal provisions based on information at (1) and (2).

The designer makes use of the above information and the soundness of his design depends upon the quality of this information. The regularity with which structures fail due to wind indicates that they are designed on the basis of data, which does not fully represent the reactions of wind on structures and the analytical procedures adopted do not represent actual behaviour of such structures. All the three facts of information therefore need close scrutiny and detailed study.

3. ANALYTICAL WORK

The Committee had set up a sub-committee consisting of Prof. G.N.V. Rao, Prof. N.C. Nigam, Prof. Prem Krishna and Dr. B. Venkateswarlu to look into the research needs, corresponding facilities available and the augmentation required therein. This section of the report is based largely on the findings of the subcommittee and subsequent deliberations of the committee in the matter.

The study of Civil Engineering and other Structures under wind Effects can be divided into the following parts:

1. Analytical study of structures for known wind load models during storms and circulatory motions such as cyclones and tornadoes.
2. Study of rigid models of conventional structures for determination of pressure distributions, and aero-elastic models of flexible structures to study their aerodynamic response.
3. Experimental work on prototypes. Prediction of behaviour of structures under wind loads could be placed on a more dependable footing by combining work at (1) and (2) and verifying it with observed behaviour in the field.
4. Similar to (3) above, invaluable information can be obtained through study of damage caused during extreme winds and analysing it backwards for obtaining data on wind forces.

3.1 Present Status

The current state-of-the-art in respect of studies needed, the capabilities within the country and outside can be summarised briefly as follows:

Theoretical Work:

The effectiveness of any exercise in the analysis of structures - whether static or dynamic - is dependent a great deal upon the accuracy with which the structure and the loads are modelled. It can be said with confidence that the state of knowhow on mathematical modelling of structures and their analysis under given static or dynamic loads is excellent within the country as well as in other countries.

Despite the availability of knowhow for analysis, only a limited range of structural analysis problems under wind effects have been tackled, and much needs to be done on this front. There is however, as yet a wide gap between the availability and requirement of information on wind load spectra both in the frequency as well as the time domain.

A prerequisite to undertaking a laboratory programme of studying the effect of wind loads on structures is the availability of adequate low speed boundary layer wind tunnel facilities. Most wind tunnels in this country were planned initially for aeronautical purposes. Some of these have been used in recent years for industrial testing and this has its limitations. Some boundary layer tunnels are now being setup - see Table 1.

Most of the existing wind tunnels have certain inherent handicaps in relation to the testing of structural models - one such factor being the limited length of test section, whereby adequate boundary layer thickness is not produced thus inhibiting the size of model that can be tested within the boundary layer. This leads to the difficulty of obtaining Reynold number R_n , values much smaller than those occurring in the field. Even if, alternatively, boundary layers are simulated with the use of grids, the turbulence intensity falls well below the atmospheric values. Most of the tunnels also have a small cross section so that only models of small structures can be accommodated.

It is well known that there is considerable difference between model R_n values and full scale values. After long and careful consideration of the problems, the practice of carrying out tests at slightly below the critical Reynolds number (about 3×10^5 for a circular cylinder) has been followed, since the results thus obtained are likely to be somewhat closer to full scale values and corrections for the differences in Strouhal numbers and drag coefficient can be made. Experience with roughening the surfaces of smooth boundaries has not been happy, mainly because the operating point tends very often to the bucket region, if the size of the roughness element is such as not to affect seriously the measured drag or oscillatory lift coefficients. Corrections to model values due to differences are possible but more full scale data is required to be confident.

The limitations of these tunnels and the modifications required are in general given in Table 1. However, in a few of the tunnels (existing or under construction) with comparatively inexpensive augmentation of the existing facilities, the tallest structures envisaged in the country so far, can be tested with a model scale of 1:200 (see Table 1).

It is also important to note that centres where capability for industrial testing currently exists are unable to cope up with the demand for such work, since tunnels being used are part of aeronautical setup and have to give priority to aeronautical work, test programmes are delayed considerably. Therefore, as the demand for industrial testing increases, several well developed centres with industrial wind tunnels will be required to cope up with it.

The next important requirement for laboratory studies is the capability to produce good aeroelastic models. There is no problem in making rigid models for pressure distribution studies. But aeroelastic models are obviously more difficult to make and prove to be more expensive. Work at I.I.Sc., Bangalore, as well as at the University of Roorkee, Roorkee in recent years, has shown that good aeroelastic models can be made in this country. It will nevertheless be valuable to learn from the greater experience abroad where better facilities exist for making aeroelastic models.

High quality work on wind tunnel models requires availability of extensive and sophisticated instrumentation. Such instruments as, hotwire or laser anemometers, pressure transducers, non-contact probes with multi-channel circuitry, data logging and processing units etc. are required to give a full range of capabilities. Much of this instrumentation can be available in India, though not as sophisticated as that available abroad, and the rest can be imported, if funds are available. It must be admitted that more experience exists abroad on the manufacture and use of such sophisticated instruments.

The step that follows the measurement and processing of results is their interpretation to predict prototype behaviour. The rudiments of this problem are reasonably well understood as institutions in India where such studies are in progress, though greater experience is generally expected on this aspect too, at well established centres abroad. It is noteworthy in this context that results obtained in case of some bridge studied from consultants abroad have been bettered through indigenous effort.

Prototype Measurements:

Very little effort has yet been made to monitor response of existing structures by instrumenting them, although this can yield very valuable information. A few studies on tall towers and buildings are reported from abroad but none in India. Admittedly such studies will need substantial resources, both in instrumentation and infrastructural, as well as the willingness of owner agencies to allow experimentation to be carried out on their structures.

The current situation in our country is that some owner agencies have indicated willingness to permit instrumentation of their tall towers or chimneys but the necessary instruments and the setup to monitor and maintain these is not yet available.

3.2 Types of Structures Required To Be Studied and Special Features :

The broad classification of the types of structures for which model testing is considered necessary is given below with a brief description of each. Structures can be conveniently divided into (a) tall flexible structures, (b) short and medium height or long span structures and (c) low cost structures.

There is sufficient experience to show that the problems associated with model studies of each of the types of structures in wind tunnels are substantially different and they are therefore discussed separately below.

Tall flexible structures:

Most tall flexible structures such as chimneys, TV and microwave towers, high rise buildings, masts etc. have slenderness ratios in the range of 10 to 20 and it is anticipated that many structures with heights 50m to 350m are likely to be built in the country in the foreseeable future. Models of these structures have to be tested not only for direct wind load, but also to assess their dynamic response characteristics due to vortex excited oscillations, atmospheric gusts and cyclones. For making models of these structures, experience indicates that the least significant part of the structures should exceed a dimension of about 2 mm in the model, with a reynolds number of at least 5×10^3 . If rounded structures are to be examined, suitable roughening of the models, to achieve conditions that would allow extrapolation to full scale, should be devised. Finally, the size of the models by themselves should not lead to a blockage of more than about 2 percent of the wind tunnel cross sectional area but this condition can be relaxed when the surrounding structures are modelled.

Medium-size structures:

Structures of heights varying from 15m to 50m and with slenderness ratio from one to ten are covered in this grouping. Typical examples are multistoried buildings of more than five stories, elevated water towers and transmission line towers. In such structures, the major aspects requiring model studies are apart from direct load, the effect of permeability, shape and shielding by other structures. Detailed experiments are also necessary to study the dynamic effects of wind.

The low rise structures:

Low rise structures are those with slenderness ratio of the order of one or less. Their heights may be upto 15 meters and they may be quite wide. Typical examples are, factory buildings, aircraft hangers, oil tanks, etc. In such structures, the major aspects requiring model studies are, apart from direct wind load, the effect of permeability shape, projections, shielding by other structures, and other local characteristics such as the surrounding terrain. Detailed pressure surveys are usually necessary in such studies.

Long span structures:

Such structures include bridges of long spans such as cable stayed or suspension bridges, roofs of different types. Roofs with large span are domical, arch, shell or suspended cable structures with curved surface, Detailed pressure distri-

bution studies and aerodynamic effects of vortex shedding or gusts are required for these roofs. The bridges need be studied for their aerodynamic stability.

Low cost and light weight structures :

A new area of study which has come into prominence is that of the low cost and light structures. Examples are rural dwellings made of cheaper light weight materials, temporary industrial type structures and cyclonic shelters. It is obvious that the effects of wind on such structures, both static and dynamic, should be evaluated with great care. There is urgent need to establish guidelines for the design of such structures.

3.3 Areas of Research :

Considering the developments in this country and needs for updating the design codes, the following areas of research using wind tunnel models are identified.

- a) Effects of wind loads on transmission and other tall latticed towers.
- b) Wind effects on solitary cooling tower.
- c) Wind effects on tall concrete towers and chimneys.
- d) Wind effects on tall composite (concrete+steel) towers.
- e) Wake-interference effects between groups of chimneys, cooling towers and buildings.
- f) Wind loads on curved roofs both rigid and flexible one.
- g) Effects of terrain roughness on wind loads for all structural forms in (a) - (f).

The study of aerodynamic effects for all the above forms is intended to be included.

- h) Galloping of different type of transmission lines.
- i) Drag of box girder type bridge cross sections.
- j) Shielding effects in space frames.
- k) Guidelines for the design of rural dwellings, including design of wind breakers.
- l) Erosion of building surfaces due to wind laden with rain, snow or sand.

3.4 Augumentation of Facilities Needed :

The augumentation needed to the larger tunnels at the I.I.Sc., Bangalore, IIT Kanpur, and the University of Roorkee are listed below :

- a) Providing suitable rotation platforms, boundary layer simulation and moving belt facilities.
- b) Increase the power of the proposed Roorkee University 2m x 2m wind tunnel to achieve a maximum wind speed of 75 m/s, and more accurate speed control. This is a new facility being put up with DST support and already has a long test section enabling formation of a thick boundary layer.
- c) Improved instrumentation and data collection facility for better quality results. There include a laser anemometer, multichannel recording and data acquisition system and sensors with associated circuitory.

Further, in order to give a better regional distribution of industrial testing capabilities, the wind tunnel facilities at IIT Kharagpur may also be augmented to provide for a medium size industrial tunnel. Also, in view of the importance of studies on cyclone effects it is recommended that one or two of the existing tunnels may be modified to incorporate capabilities for cyclone simulation.

The above recommendations are made with a view that the facilities that will thus become available at the various institutions, will together be able to handle the models for tallest and the largest structures in the country, and will also be able to tackle the research problems listed earlier. Development of facilities at a number of places is necessary to cope up with the expected work load of testing models of future design for wind sensitive structures, as well as to give adequate impetus to the research effort needed. It may be mentioned that since models are often built in the tunnel for testing, every test engages a tunnel for a considerable time. That necessitates having several well equipped tunnels in the country.

In the long range perspective, provision may be made for a large multi-purpose and National facility to cater for industrial testing purposes and testing of atmospheric flight vehicles. Such a facility may cost in the region of Rs.10 crores and its creation may be considered when funds of this order are available.

Data for Major Wind Tunnels in the country is given in Table 1.

DATA FOR MAJOR WIND TUNNELS IN THE COUNTRY

TABLE - 1

Sl. No.	Wind Tunnel	Present Deficiency	Immediate Modification required	Maximum height of str. that can be modelled on scale of 1/200 and tested
1	2	3	4	5
1.	I.I.Sc. 4.25mx2.75m	No integral rotating platform, no integral boundary layer generating set-up, NOT POSSIBLE TO SIMULATE CYCLONIC EFFECTS, no moving belt and no thermal stratification of flow possible.	Provide integral rotating platform modify first contraction to install boundary layer simulation apparatus.	350 m
2.	I.I.Sc. 2.5m x 1.5m	No integral rotating platform, no integral boundary layer generating set-up, NOT POSSIBLE TO SIMULATE CYCLONIC EFFECTS, no moving belt and no thermal stratification of flow possible.	No modifications proposed now.	175 m
3.	I.I.Sc. 4.57mxdia jet	- do -	- do -	Not suitable
4.	N.A.L. 2.75mx1.8m	- do -	- do -	175 m
5.	N.A.L. 0.91mxdia jet	No integral rotating platform, no integral boundary layer generating set-up, NOT POSSIBLE TO SIMULATE CYCLONIC EFFECTS, no moving belt and no thermal stratification of flow possible.	All modifications possible but in view of small size, will be of very limited utility.	50 m
6.	I.I.T. Kanpur 0.9mx0.6m	- do -	All modifications possible but in view of small size, will be of very limited utility.	50 m
7.	I.I.T. Kanpur 3.05mx2.13m	Rotating platform and boundary layer generation being incorporated in design.	Other features can be incorporated if funds are available, since the wind tunnel is still in the design stage.	200 m

(Table - 1 continued)

1	2	3	4	5
8.	I.I.T. Madras 1.5m dia	Not being primarily designed for wind engineering studies.	No major modifications contemplated	50 m
9.	I.I.T. Madras 1.5m	No integral rotating platform, boundary layer generating setup, moving belt thermal stratification or cyclone facility.	Other features can be incorporated.	200 m
10.	Indian Institute of Tropical Meteorology Poona 1.0mx 1.0m, not operational but intended mainly for boundary layer and thermal stratification studies.	No integral rotating platform, moving belt or cyclonic simulation contemplated.	Even if modified with rotating platform etc. will be of limited use for applied wind engineering studies.	50 m
11.	University of Roorkee 1.0mx0.9m	No integral rotating platform, moving belt boundary layer simulation facility.	Modifications possible to have all facilities but will be of limited utility in view of small size of wind tunnel.	100 m
12.	University of Roorkee 2mx2mx2m	Boundary layer generation being incorporated in design but there is no thermal stratification or cyclone facility. but present design speed of 20m/sec. is rather low.	Since the wind tunnel is still being designed other features can be incorporated if funds are available.	200 m
13.	I.I.T. Kharagpur 0.61mx0.61m	Test section small	-	-
14.	I.I.T. Kharagpur 0.61 gust tunnel.	-	-	-

4. WIND ZONING AND CODAL PROVISIONS

Code provisions contained in the various Indian Standards for design of structures duly provide for the consideration of wind effects in the design of structures in many categories of buildings, towers, bridges, industrial structures. The provisions are made on the basis of existing information on the character of wind and its effect on structures. However, the provisions are not always adequate to ensure the safety of structures. This is obvious from the frequent failures of structures, ranging from ordinary dwellings to flexible towers and bridges under wind storms. This problem will assume greater importance as we tend to use lighter, larger structures which will be wind sensitive to a greater degree. On the other hand, there is also the possibility that wind effects are over estimated in some other cases, and thus the provisions need be reviewed from time to time. Such state of affairs prevails because of shortcomings in available information about wind loads as well as structural response to them. The Indian codes of practice which specify wind loads on different structural forms tend to be rather sketchy, partly, due to the handicaps mentioned above. The Indian codes, as at present, give the following information :

- i) Wind pressures varying with height upto 150m above ground level for various parts of the country, on the basis of extrapolations.
- ii) Pressure coefficients or shape factors for certain types of structural forms industrial sheds, tower, bridge girders, cylindrical forms etc. based on work done outside India.

In this context Annexure A₅ prepared by the ISI furnishes valuable information.

For updating the codes to make them more rational and comprehensive on the basis of data and work in this country, following suggestions are made for further work:

1. Preparation of wind maps giving return periods and their significance in determining design wind. On the basis of historical data, it should be possible to prepare Return-Period maps as available in U.S. and B.S.S. code and to provide charts for computing design wind velocity (hourly Mean and/or Gust) for a specified exceedance probability and service life of the structure.

The feasibility of specifying probability distributions of path length, path width and the frequency of occurrence of Tornadoes and Hurricanes over some parts of the country may also be examined.

2. Description of the types of storms including storm surge due to cyclones in coastal areas.
3. Assignment of suitable importance factors for design of different structures.
4. Influence of terrain conditions on mean wind and gusts.
5. Dynamic effects of wind gusts.

The method of adding the dynamic stresses due to wind to the other stresses should be clearly spelled out as in the case of earthquake analysis.

6. Aerodynamic behaviour of flexible structures such as tall towers and wide span bridges etc.
7. Exhaustive list of shape factors/pressure coefficients, to be prepared on the basis of work already reported and with the help of further studies. For example, the drag coefficient at higher Reynolds number of circular cross sections appears to be nearer 0.8 than 0.7. Similarly, it is very essential that a rational pressure distribution for cooling towers should be evolved on the basis of Indian studies.
8. Wake-Interference effects.

It should be mandatory requirement, that if there are identical or nearly identical chimneys, which are separated by distances of less than 20 diameters or $2/3$ their heights, wind tunnel tests should be carried out to ensure that large dynamic stresses due to aerodynamic interference are not set up. Specifically the codes may recommend remedial measures such as strakes (discrete and continuous).

Information on some of the above aspects can be obtained on the basis of analytical work done in this country and in other countries, where applicable to Indian conditions. This would be possible more easily where analytical aspects are concerned. However, where the characteristics of the wind environment are concerned there is not much alternative to producing our own information. Towards this end, it will be most fruitful if an organisation, such as the SERC Madras, will publish relevant wind data of selected stations in different parts of the country as a regular exercise every 3 months, under a suitable arrangement with the IMD (source of the data being duly acknowledged). Further, it is essential that extensive effort is made to obtain more dependable data, by setting up adequate number of wind monitoring stations to measure velocity, pressure, their variation with height and time, particularly in areas prone to be hit by wind storms and cyclones. In most cases, at present, the velocity at a single fixed height only is obtained.

5. WIND DATA

Indian Meteorological Department is primarily responsible for routine measurement of wind (both surface and upper air) from different locations of the country. Two types of wind measuring instruments - electrical and dines PT anemographs are normally used. The distribution of wind measuring stations operated by IMD is given in the map. It may be seen that IMD is operating 25 dines PT anemograph stations and 17 electrical anemograph stations. In addition there are 31 wind observing stations being operated by departments other than IMD to meet their specific requirements.

Table 2 shows the position of observational arrangements of wind measurements, level of observations and number of stations that are being operated by IMD.

TABLE - 2

Type of Wind observation	Levels of observations	No. of stations in India
1. Autographic records	8-10m a.g.l	70
2. Continuous measurement of wind over tower	2, 4, 8, 16, 32, 48 and 64m a.g.l	1
3. Pilot Balloon	.15, .3, .6, .9, 1, 5km	62
4. Radio and Radar wind	.15, -do-	32

The above mentioned data is usually (except in the Vizag tower) obtained at a standard height of 10m, or 150m and above.

The Committee considered the requirement of type of instruments, the range and accuracy of observations for obtaining adequate and reliable wind data which can be used for specifying structural design loads. Accordingly, it was identified that the following types of instruments (with given specifications) ought to be available, and measurements made at different height upto atleast 150m above ground level.

1. WIND DIRECTION SENSOR FOR STUDYING WIND EFFECTS ON BUILDING AND STRUCTURES -
 1. Range 0 to 360°, continuously rotatable
 2. Maximum dimensions including those of pack-offs 30cms x 30cms x 30cms
 3. Weight Indicator plus pick off weight should not exceed 5 kg.

- | | |
|------------------------------------|---|
| 4. Sensitivity | $\pm 1^\circ$ |
| 5. Minimum wind speed for response | 2 km/hour |
| 6. Design maximum wind speed | 320 km/hour |
| 7. Time Constant | Defined as the time needed to change 0.9 degrees when the wind direction changes by one degree; 0.2 seconds at 50 kmph. |
| 8. Output | Maximum electrical output shall be 5 v. DC |
| 9. Linearity | Deviation must be within 0.3 degrees at all angles. |

2. ANEMOMETERS FOR STUDYING WIND EFFECTS ON BUILDINGS AND STRUCTURES

- | | |
|--|---|
| 1. Range | 0-320 kmph |
| 2. Maximum dimensions excluding mount, but including attached pick-off | 20 cms x 20cms x 20cms |
| 3. Weight | Weight of anemometer and pick-off not to exceed 5 kg. |
| 4. Starting speed | Less than 1 km/hour |
| 5. Sensitivity | 0.5 kmph at 100 kmph |
| 6. Time Constant | Defined as time to attain 100.9 kmph from 100 kmph when there is a step increase in wind speed from 100 kmph to 101 kmph:0.2 seconds: |
| 7. Electrical output | Maximum, 5 VDC |
| 8. Linearity | Better than 0.5% |

3. GUST PROBE

Maximum safe wind speed	320 kmph
Maximum dimensions	10 cm
Preferred maximum dimension	5 cm
Natural frequency	>30 Hz.
Frequency response	0.5 Hz to 1.5 Hz
Min. turbulence signal sensed at a mean wind speed of 60 kmph.	.5% in 3 mins.

It may be seen from appendix A₆ and A₇ prepared by the IMD that the IMD instrumentation does not quite meet the above specifications. This is understandable since it is not the main IMD function to provide for design wind loads. Therefore the existing IMD stations particularly in the coastal region (and a chosen few to begin with) should be strengthened with the type of instrumentation as described above. These instruments have either to be developed indigenously or otherwise.

The Committee felt that the following organisations/
Institutions had the capability to develop one or more of these
instruments :

Indian Meteorological Department

Vikram Sarabhai Space Centre

National Aeronautical Laboratory

Solid State Physical Laboratory

Indian Institute of Science

CSIO, Chandigarh

USIC, University of Roorkee

Aeronautical Development Establishment.

It is realised that intensive instrumentation of a tall structure and measurements of Wind data and structure response will be an expensive exercise if carried out on a large number of structures. However this yields invaluable information. Therefore it is recommended that 5 tall towers/chimneys/buildings may be picked up in the first instance at chosen locations (Madras, Vishakhapatnam, Balasore, Delhi, Varanasi/Bombay) and studied. The committee noted that the Vizag tower is already instrumented by the IMD upto a height of 65m, but the arrangement will need to be strengthened. The Committee was informed by

Prof. G.N.V. Rao that some user agencies - Badarpur thermal power station, Singrauli power station, Bombay TV - have indicated that they will consider favourably the proposal for instrumenting their structures.

In the opinion of the committee the structure should be instrumented at a minimum of 3 levels with the following for measurement of response.

1. Accelerometer
2. Displacement meter
3. Strain measuring arrangement

Accelerometers with the following specifications need to be developed :

- | | |
|--|--|
| 1. Range | Maximum 1 g (980 cm/sec^2) |
| 2. Shock limit | 25 g |
| 3. Mounting | Horizontal axis |
| 4. Minimum measurable acceleration | 25 micro meter/ sec^2 |
| 5. Electrical output at minimum acceleration | 25 micro volts |
| 6. Frequency Response(3db) | 0.2 Hz to at least 250 Hz |
| 7. Mounted Response frequency | Ten times the maximum frequency response |
| 8. Weight | Can be upto 5 kg. |
| 9. Maximum operating temperature | 80° C |
| 10. Minimum operating temperature | 5° C |
| 11. Voltage attenuation due to 500 meter length of output cable must be less than 0.5%, when the signal from the accelerometer is fed to a system with an input impedance of one megohm. The supplier shall specify the value of by-pass condenser that can be incorporated. | |

Further for the measurement of wind data the structure should be instrumented at a minimum of 5 levels with the following:

1. Direction Sensor
2. Anemometer
3. Gust probe.

6. INFRASTRUCTURAL ARRANGEMENTS

6.1 Education

The Committee deliberated on the need to educate technical personnel on problems related to wind engineering. A survey was conducted by ISI to determine the present status of this aspect and a summary of the report thereon is as follows :

The questionnaire was sent to 112 Engineering Colleges, in the country having degree level teaching programme in Civil Structural and Electrical/Telecommunication Engineering. 21 colleges responded, 3 of which gave a 'Nil' report for the entire questionnaire. The replies of other 18 colleges are summarised below :

A. Teaching

- A-1 16 colleges indicated that wind aspects are covered in their teaching programme.
- A-2 The colleges have given details of their courses and most of them have indicated that relevant Indian Standards are included in the course content.

B. Research

- B-1 During the last five years five of the colleges conducted research programmes in wind engineering leading to 8 Thesis for M.Tech/Ph.D.
- B-2 During the last five years, five of the colleges published 12 papers in the area of wind engineering.
- B-3 Most of the colleges have given the list of faculty members interested in this field.

C. Design

- C-1 During the last five years six engineering colleges completed 16 projects in the area.

D. Any other information

Some colleges have furnished details of their programmes planned for the future as well as their involvement in this field in conjunction with other agencies.

The detailed report is annexed as A₈

It is apparent that the subject is receiving rather limited attention in the educational programme. In view of its importance for mitigating the disastrous effects of high winds, the educational programme needs to be strengthened as follows :

1. The subject "Wind Engineering" should be introduced at the under-graduate level as a part-course in the Civil, Electrical and Electronic engineering disciplines as well as to the Architecture classes. A full elective may also be introduced at the graduate level in the Civil Engineering discipline.
2. The ISI/NBO may take up the task of educating the in-service engineer, in collaboration with teaching/research institutions by offering short courses.
3. An awareness seminar may be held on the subject at the earliest involving the scientists, engineers, educationists and planners. This should be followed by a technical symposium which should become a 4-yearly feature.

6.2 Coordination of Research :

There is at present no organised effort to promote, monitor and coordinate research in the field of wind engineering in the country. There is an urgent need to provide such a platform. It is recommended that a standing committee be set up at the National level by the Department of Science & Technology for this purpose. The committee should draw members from the following :

1. An eminent engineer/scientist Chairman
2. Representatives of IMD, ISI, NTPC and CPWD.
3. Representatives of Ministries of I & B, Education, Science and Technology.
4. Representatives of University of Roorkee, IISc., Bangalore, IIT., Kharagpur and SERC Madras.

The committee should be responsible for promoting research in areas of importance, for monitoring the progress of such work and advice on other related effects such as education and standardisation. Further, the committee should liaise with National and International organisations such as the International Association of Wind Engineering, UNESCO, UNDRO etc. and advise the Government on action needed. The committee should also vet specific proposals for research and collaborative programmes with foreign institutions.

Annexure A₁

List of Documents Considered by the Committee:

1. Note on wind observation by Dr. P.K.Das
2. Note on coordinated R and D programmes, review of I.S. code and Wind zoning by Prof. N.C.Nigam.
3. Note on Wind speed observations, R and D programmes on Instrumentation, need for change in code provision and wind engineering problems by Prof. G.N.V.Rao.
4. Note on wind induced force on structure and an account of damages due to cyclone in Andhra Pradesh by Dr.B.Venkateswarlu.
5. Note on Wind Engineering problems that can be handled by Universities by Prof. Prem Krishna.
6. Note on loss of life and property inflicted by Wind Storms by Shri G.C.Mathur.
7. Report on Wind Tunnel facilities in the country by sub-committee formed by the Main Committee.
8. Effect of wind on common man's dwellings by NBO.
9. Research Work related to static wind load and dynamic wind forces on structures and buildings by NBO.
10. Design of common man's dwellings to resist cyclone wind forces by SERC.
11. Note on code provision in the country by ISI.
12. Note on the present status and future scope of education and training of engineers in wind engineering problems by ISI.
13. Present status of instrumentation for the measurement of mean velocity of wind from levels 1.5m to 150m above ground.
14. Note on existing network of wind observing stations alongwith types of measurements by IMD.
15. IMD's plan proposal for instrumentation for TV towers and its present station by IMD.
16. Research needs and related facilities by Prof.Prem Krishna.
17. Deficiencies in present Indian Standards for wind loading by Prof. Prem Krishna.
18. Scheme on Wind Engineering Study by IMD.
19. Status of Wind observation at Vishakhapatnam tower by IMD.
20. A report on the present status of work and future plan of activities in the aeronautical department IIT., Kharagpur by Prof. B. Basu.

Annexure A₂

Minutes of the Committee Meetings

(Meeting held on 1st December, 1980)

Present :

- | | | |
|--|-----------------|------------------|
| 1. Prof. Jai Krishna, University of Roorkee. | | Chairman |
| 2. Dr. P.S.Pant, IMD | X | Rep.Dr.P.K.Das, |
| | X | |
| 3. Dr. B.P.Murty, IMD | X | DGM, IMD |
| 4. Prof. G.N.V. Rao | IISc, Bangalore | |
| 5. Prof. N.C.Nigam, | IIT, Kanpur | |
| 6. Dr. B.Venkateswarlu, SERC | | |
| 7. Prof. Prem Krishna, University of Roorkee | | |
| 8. Shri K.K.Sharma, | ISI | |
| (Rep. Shri G.Raman, Director, ISI) | | |
| 9. Shri K.S.Srinivasan, NBO | | |
| (Rep. Shri G.C.Mathur, Director, NBO, New Delhi) | | |
| 10. Dr. D.K.Rakshit, | DST | Member-Secretary |

The members were informed that on the advice of the Chairman, Shri G.Raman, Director, Civil Engineering, ISI has been co-opted as member in place of Shri Ajitha Simha, ISI who has taken up his new assignment and posted at Madras.

Dr. P.K.Das, Shri G.C.Mathur and Shri Raman could not attend the meeting but deputed their representatives to the meeting. The following background notes prepared earlier by members were circulated.

- (1) Note on Wind Observation by Dr. P.K.Das.
- (2) Note on coordinated R&D programmes, review of IS Code and wind zoning by Prof. N.C.Nigam.
- (3) Note on wind speed observations, R&D programmes in instrumentation, model test, need for change in Code provision and wind engineering problems by Prof.G.N.V.Rao.
- (4) Note on Wind induced force on structures and on an account of damages due to cyclone in Andhra Pradesh by Dr.B.Venkat-eswarlu.
- (5) Note on Wind Engineering problems that can be handled by Universities by Prof. Prem Krishna.

- (6) Note on loss of life and property inflicted by wind storms by Shri G.C.Mathur.

The Chairman in his introductory remarks mentioned that the problem of wind effect mitigation on structures and buildings during high wind associated with cyclonic storms, tornadoes etc. were discussed at different forums and relevant studies are being made in different universities, institutes and national laboratories. In order to make the present research effort more effective and useful there is a necessity to look at the total aspect of research effort being made in different institutions and universities, identify the gaps both in terms of infrastructure and equipment facility so that useful R&D programmes could be suggested. He also made a reference to the last Indo-US Workshop on Natural Disaster (Earthquake and Wind Effect) Mitigation Research held in December 1978 which recommended that there should be a Wind Engineering Council in the country to formulate and coordinate future R&D programme in this area. He appreciated DST for pursuing the follow-up of the recommendations of the above Workshop and setting up this Committee. While referring to the terms of reference of this Committee he stated that these are quite exhaustive and invited any comment from the members. There was no comment on the terms of reference.

Dr. P.S.Pant, IMD, while presenting the report earlier prepared by Dr. Das stated that the wind instruments operated by IMD are primarily meant for synoptic scale study for weather forecasting purpose and thus these instruments are not rugged enough and designed to withstand maximum wind force during cyclonic storms or tornadoes and also that the wind observation at higher speed, say more than 150 km/hour, is not that accurate which could be utilised for studying wind engineering problems. As regards measurements of gusts and turbulence from the existing wind observation it was stated that while gustiness is determined from the records of Vmax and Vmin, the turbulence factor cannot be easily determined from the existing chart records which are slow moving. It was felt that there is urgent need to acquire instruments which can measure reliably the gusts and turbulence during cyclones etc. In this context Prof. Nigam informed that some work on the measurement of gusts have been done by ADE and VSSC. Prof. Nigam was requested to supply a more detailed information on this.

After a detailed discussion it was felt that though the wind information from the existing network of wind observatory of IMD provides very useful information for wind engineering study, sophisticated wind measuring devices are to be introduced in the country to collect data as required by Wind Engineers. While the need for wind data at maximum wind speed during cyclones, tornadoes etc. were well realised, members felt that wind data at different levels upto 300 m from the ground level would also be required very much for wind engineering problems. In this connection, the possibility of wind

observations from existing tall towers was discussed. Dr. Pant stated that IMD had a proposal to put up Wind Measurements in the existing TV towers but they did not receive any favourable response from the AIR. Members felt that even if the tower wind is available there would be a necessity to examine the interaction between the tower and the wind measurement to derive the correction factor before it is used for wind engineering problems. In this context, Dr. Pant stated that a set of instruments have recently been installed in a tower at Vizag and the performance of these instruments is under observation. It was suggested that more towers of Vizag type should be utilised for wind observation. On a point about reliable wind observation at higher wind speed, say upto 200 km/hour, representative of IMD stated that such wind measuring instruments are available commercially in other countries. As regards calibration of these wind observing instruments it was understood that with the existing wind tunnel facility in the country wind instruments recording upto 120 km/hour can only be calibrated.

Mr. Sharma of ISI stated that he consulted the codes on wind load introduced in other countries and he observed that there is enough scope and justification to revise the existing Code IS-875 which was devised about 16 years ago in 1964. Prof. Nigam referred to the Swiss code and BS code which contain more information than our code that was prepared long ago based mainly on return period of wind published at that time by Iyer & Goel. He also mentioned that statistical approach of wind should be provided in the code. Dr. B.P. Murty while supporting the above view stated that ISI code was devised on the basis of wind zoning map available at that time but during this long period besides substantial increase in the number of wind observing stations the quality of observation has improved. In this context, the need for preparation of Indian Standard Atmosphere was also raised. Dr. Rakshit intimated that a few groups in Bangalore, Trivandrum and Ahmedabad are already working on Indian Standard Atmosphere and some reports are already available. It was decided that a report on the present work of Indian Standard Atmosphere would be prepared and circulated to members.

As regards acquiring wind instruments that could measure high wind speed, it was decided that IMD would collect all relevant information of high wind measurement and suggest our own instrument development programme. In this context, a suggestion was made that to save time it would be worthwhile if we could import one or two such instruments and try to copy the same in the country. It was agreed that IMD would be requested to prepare a note on instrument development programme.

Prof. G.N.V.Rao while presenting his note emphasised on the need for model test in wind tunnel. He stated that there is at present no rotating platform in the wind tunnel of IISc Bangalore due to which effect of wind from different directions cannot be studied. He also mentioned that IISc Bangalore has been receiving a large number of enquiries from many users to make model test in wind tunnel. In this context he mentioned that the wind tunnel at IISc Bangalore is not capable of handling all wind engineering problems and stated that a large industrial type of tunnel would very much be needed to satisfy the needs of all users.

Prof. Nigam while presenting his note emphasised on the need to collect wind tunnel data for solving many wind engineering problems. He referred to the Valluri Committee report on Aeronautical aspects and stated that the problem should be extended to the requirement of industrial type of wind tunnel.

Dr. Venkateswarlu while presenting his note described various wind engineering projects undertaken by SERC. As regards disseminating information on the designing of common man's dwellings, Dr. Venkateswarlu stated that while SERC could supply the required technical information, the NBO should take action to disseminate/publish such information. The account of damages during Andhra Pradesh cyclone of 1977 as submitted by Dr. Venkateswarlu was discussed in details. In view of the importance of loss to common man's houses during cyclones the committee felt that NBO should compile all information available with different institutes in the country and disseminate to various users how to safeguard common man's dwellings from cyclone damages. It was understood that an exhaustive note on the storms effecting the east coast during 1881-1970 prepared by R.Chellappa and B.R. Seshadry is available which is worth studying by the committee. It was decided that IMD would make available copies of the above note to the members.

As regards post cyclone survey of the affected area, representative of IMD stated that there is a procedure in IMD to send an expert to the cyclone affected area for the preparation of a report of damages caused by wind. After a discussion it was felt necessary that this survey team of IMD should include engineers from at least SERC and NBO so that the report becomes more useful for designing wind resistant houses and structures in cyclone prone areas.

As regards the requirement of wind observation from network of stations the Committee decided to recommend that there should be a wind observing station at every industrial town and also at different terrain conditions where there is drastic change in topography.

Prof. Prem Krishna while submitting his note stressed the importance of prototype and model study in wind tunnel. In this context he stated that University can make very effective contribution in the analytical studies of response of structures.

The requirement of proper size wind tunnel facility in the country was extensively discussed. In view of the great necessity of model test in wind tunnel study and that the available wind tunnel cannot meet the requirement, the Committee decided to make suitable recommendations on this. For this purpose it was felt necessary that a core group should look into this aspect in greater depth and accordingly it was decided that a Wind Tunnel Sub-Committee would be set up with the following members :

- (1) Prof. G.N.V. Rao, IISc, Bangalore Convenor
- (2) Prof. Nigam, IIT, Kanpur
- (3) Dr. B.Venkateswarlu, SERC Madras
- (4) Dr. T.N.Krishnaswamy, IISc Bangalore
- (5) Prof. Prem Krishna, Roorkee University

It was decided that this Committee would be requested to submit its report within two months.

For the convenience of the subsequent meeting, it was decided that concerned members/organisations will collect/furnish materials/documents as listed below :

1. IMD - (a) Present status of instrumentation for the measurement of mean velocity of wind from levels 1.5 m to 150 m above ground. For this time constant of instruments should be better than 0.2 sec. Information available with Prof. Narasimha's group in IISc Bangalore may also be used.
 - (b) Map showing the location of existing wind observing stations alongwith types of measurements.
 - (c) IMD plan proposal for instrumentation on TV towers and their present status.
 - (d) Compilation and supply list of documents/references which contain information relating to wind observation.
 - (e) Copy of note prepared by Chellappa & Seshadri on storms effecting eastern coast during 1881-1970.

(f) IMD will collect information about wind measuring INSTRUMENTS in other countries and prepare a note on wind Instruments development programme. In this connection, Dr. G.N.V. Rao will supplement information that he will collect from USA.

2. SERC - Preparation of a note on technical information relating to common man's housing related to wind engineering - contribution made so far by SERC.
3. NBO - Note on the present status of publication of information on common man's dwellings vis-a-vis wind effect.
4. ISI - (a) To prepare a note on the code provision in the country and make a comparative chart with reference to those in other countries.

(b) To prepare a note on the present status and future scope of education and training of engineers in wind engineering problem.
5. Prof. Nigam - To make a note on work done by ADE and VSSC on gust measurement.
6. Roorkee University and IIT Kanpur - Prof. Prem Krishna and Prof. Nigam will prepare a note on wind force effect on chimneys, cooling towers and other towers. NBO will collect information on existing research work relating to static wind load and dynamic wind force on structures/buildings from respective engineering colleges and passed them on to Prof. Prem Krishna and Prof. Nigam.
7. DST - (a) DST will formally set up the sub-committee on wind Tunnels.

(b) DST will obtain comments from AIR, Railways about the proposal of utilising their towers for wind observations.

(c) A note on the present work on standard Atmosphere will be prepared and circulated.

It was agreed that the next meeting of the Committee would be held early in March 1981.

The meeting ended with a vote of thanks to the Chair.

(Meeting held on 21 September 1981)

Present :

1. Prof. Jai Krishna Chairman
2. Shri S.K.Das, ADG, IMD New Delhi
3. Dr. B. Venkateswarlu, Asstt. Director, SERC Madras
4. Dr. Prem Krishna, Professor, University of Roorkee.
5. Shri K.K.Sharma, Dy.Director, ISI, New Delhi.
6. Shri R.N.Gupta, IMD, New Delhi.
7. Dr. D.K.Rakshit, PSO, DST Member Secretary

Prof. N.C.Nigam, Prof. G.N.V.Rao and Shri G.C.Mathur could not attend the meeting.

The following documents were circulated to members which were discussed at the meeting.

- i) Doc.1 - Report of the Sub-Committee on Wind Tunnel.
- ii) Doc.2 - Effect of wind on common man's dwellings and Research work relating to static wind load and dynamic wind forces on structures and buildings.
- iii) Doc.3 - Note on wind observations/Instruments.
- iv) Doc.4 - Design on common man's dwelling to resist cyclone wind forces.
- v) Doc.5 - Note on Wind forces.
- vi) Doc.6 - Present status of education/training in Wind engineering problems.

The Chairman in his introductory remarks stressed on the urgent need to finalise the report of the committee. He stated that the report may be concentrated on the following aspects of Wind Engineering.

(a) Present status of the subject and research facilities in the country, (b) Need for further research effort and identification of scientists/institutions where this work could be taken up, (c) Step wise programme of work and approximate requirements of funds (d) Conclusion and recommendations. Each participating organisation may make their notes under the above headings to facilitate compilation of the final report.

The discussion that took place and decisions taken at the meeting on various agenda items are as under :

Agenda Item 1 : Review of action taken on the minutes of the First Meeting

Shri Sharma of ISI suggested a little modification in the recorded minutes vide page 43, para 4(b). He stated that, as per decision taken at the previous meeting, ISI was to collect & compile only the present status from various engineering colleges about the syllabi of education and training which were to be passed on to Prof. Nigam and Prof. Prem Krishna for preparing a note for the Committee. After a discussion it was decided that this para will be revised accordingly. With the above change, the minutes of the first meeting were formally approved.

Dr. Rakshit while reporting about the actions taken on the previous minutes, pointed out that the note on "work done by ADE and VSSC on gust measurement" that was decided to be prepared by Prof. Nigam, was not made available as presently he is abroad. It was decided that Dr. Rakshit would get in touch with VSSC and ADE and try to obtain the relevant materials for consideration of the Committee.

Action : DST

Agenda Item 2 : Discussion on new documents

Doc.No. 1 : Minutes of the Meeting of Sub-Committee on Wind Engineering

The Committee appreciated the comprehensive note prepared by the Wind Tunnel Sub-Committee. The following points were specially noted for making suitable recommendations.

Doc.No. 3 : Status Report on Wind Measuring Instruments (Prepared by IMD)

The Committee noted the information supplied by IMD on the present status of wind measuring instruments and their distribution in the country. Members felt that there is a strong need to develop wind measuring instruments for measurement of peaks/gusts with time accuracy of 1 Sec. As wind data from high wind situation like cyclones and tornadoes are vitally needed for Wind Engineering work, it was felt necessary to develop instruments which can reliably measure wind upto 200 to 300 km/hour without depending on electric power supply, as electricity to run these instruments may not be available during cyclones etc. In this connection Dr. Venkateswarlu informed that suitable wind instruments are now available in UK and USA. IMD informed that they have got some information from USA on the latest generation of wind instruments. It was decided that copy of information received by IMD from USA will be circulated to members.

Action: IMD (Shri S.K.Das)

The Committee considered the need for measuring wind at different places vulnerable to high wind and it was felt necessary to identify 3-4 stations on the east coast, one station in the west coast and one at Delhi. In this context, Shri S.K.Das stated that IMD tried to put up wind instruments on the TV tower at Bombay but it was not yet approved by the Doordarshan authorities. Dr. Venkateswarlu intimated that SERC also was trying to utilise TV tower at Madras for putting up a set of instruments about which no decision has yet been taken. Utilisation of some of the other existing towers like that in Badarpur Thermal Power Station was considered. It was decided that Dr. Venkateswarlu will prepare a paper on wind observation on towers. It was also decided that Dr. Rakshit will write to BTPS authorities for necessary information and communicate those to Dr. Venkateswarlu for incorporating in his paper.

Action : (Dr. Venkateswarlu/Dr.Rakshit)

- (a) Only a few tunnels for industrial testing are available in the country. They were primarily designed for aeronautical testing.
- (b) Model tests for the existing tall structures can be made in the existing wind tunnels with suitable augmentation.
- (c) Many of the research problems can be undertaken in wind tunnels at Roorkee and IIT Kanpur provided the set up there are suitably strengthened. "The two institutions may prepare projects for strengthening their facilities and programmes of work to be undertaken by them.
- (d) There is a need for establishing a national facility of a large size multi-purpose wind tunnel.
- (e) There is a need for introducing a training programme at the technician level and for this purpose the facilities at IISc, Bangalore are adequate.
- (f) ISI should set up a separate wind resistance design committee.

The Committee proposed that Dr. Venkateswarlu of the SERC Madras may prepare a detailed paper on the proposed multi-purpose wind tunnel facility suitable for wind engineering studies including cyclone effects, boundary layer studies, thermal stratification etc. in consultation with Prof. G.N.V. Rao, Prof. R.Narasimha, ISI, IMD, IITM and others. It was noted that SERC Madras is already contemplating setting up a new facility. This paper will be appended to this document. It was decided that Dr. Rakshit will write to the above mentioned scientists/Institutions for supplying necessary inputs to Dr. Venkateswarlu for incorporating in the paper.

Action: (DST/Dr. Venkateswarlu)

Doc.No.2 : Information received regarding the recommendation pertaining to "Effect of Wind on Common man's Dwellings" from various department/agencies in the country. (Prepared by NBO, New Delhi)

The information contained in the document were noted.

The introduction of gust problem, turbulence probe for their direct measurement was discussed. It was decided that this aspect could be considered in a later phase.

After a detailed discussion about the future development of instruments in the country it was decided to recommend importing initially one or two suitable instruments from abroad and thereafter try to develop it in the country.

Doc.No.4 : Information on design of common man's dwelling to resist cyclonic forces.
(Prepared by SERC, Madras)

The paper on the design of common man's dwellings was discussed. It was felt that the requirement of wind tunnel test for designing common man's dwellings would be incorporated in the document and a recommendation made to the effect that existing wind tunnels can be utilised for this purpose after necessary modification/strengthening.

Doc.No. 5 : Status of Topics covered in Code of Practice for structural Safety of Buildings' Loading Standards (Revised). (Prepared by ISI)

The paper on "Code of Practice" prepared by ISI was discussed. It was noted that the present wind code is valid upto 50 m height above ground level while the present requirement is upto 350 m agl, it was felt essential to collect wind data upto 350 m agl.

The utility aspect of existing wind code for wind tunnel work was discussed. It was felt that the present code is not ideally suitable to cover all aspects of wind tunnel. It was decided that Prof. Prem Krishna will prepare a paper highlighting the deficiencies in the present code and make suitable suggestions for modification.

Action : (Prof. Prem Krishna)

It was felt necessary that the document on wind code should include a para on basic principles of ISI code, practice in USA and the need for revision of the IS code. For this purpose a comparison of IS code with US code need be made and difference highlighted with reasons thereof. It was decided that Dr. Venkateswarlu will modify the chapter accordingly taking into account the discussion on this chapter.

Action : (Dr.Venkateswarlu)

The committee discussed on the other independent means of measuring wind upto at least 150 m essentially required for wind tunnel work and for revising the existing wind code. The need for such wind data for work in other disciplines like Boundary layer study etc. were also discussed. Considering that none of the existing tower will be ideally suitable for multi-disciplinary work it was felt essential to construct a tower devoted exclusively to the above purpose. It was decided that erection of a multi-purpose tower at a cyclone prone area would be recommended.

Dr. Venkateswarlu suggested to have the tower erected at Madras in which case it would be possible for SERC to look after the maintenance etc. on regular basis. Though Madras falls under the wind vulnerable area, from the consideration of multi-purpose utility it was felt that place like Balasore in Orissa may be more suitable for the purpose particularly because IMD have a regular observatory there and maintenance would be easy. It was decided that this aspect will further be discussed at the next meeting for making a suitable recommendation.

Doc.No. 6

Summary of Information Received on
Questionnaire on Wind Engineering

The Committee noted that of the many engineering colleges approached by ISI for furnishing their status of education and training in the field of wind engineering, only 12 out of 18 institutions responded. After a discussion the Committee felt that there is a need to apprise the other institutions about the problems of wind engineering. It was agreed that a recommendation will be made to hold a symposium on Wind Engineering to discuss various problems of wind engineering and also create an awareness amongst the younger scientific community. It was also felt necessary that some of the existing institutions should introduce special course on Wind Engineering problems. It was decided that a suitable recommendation will be made on the aspect of education and training.

It was decided that the next meeting of the Committee will be held in November, and all members/organisations may prepare their notes on the times indicated by the Chairman in the beginning of the meeting. It is also proposed that all the work should be completed by the end of October so that the meeting in November could finalise the draft report.

Action: (IMD, ISI, SERC, Dr.Prem Krishna & DST)

The meeting ended with a vote of thanks to the Chair.

(Meeting held on 14 January, 1982)

PRESENT :

1. Prof. Jai Krishna, University of Roorkee Chairman
2. Prof. G.N.V. Rao, IISc., Bangalore
3. Shri S.K.Das, IMD, New Delhi.
4. Shri G.C.Mathur, NBO, New Delhi.
5. Dr. B.Venkateswarlu, SERC, Madras
6. Prof. Prem Krishna, Roorkee University
7. Shri K.K.Sharma, ISI, New Delhi.
8. Prof. B.C.Basu, IIT, Kharagpur
9. Dr. D.K.Rakshit, DST Member-Secretary

The following documents were circulated to members which were discussed at the meeting :

1. Doc.No.1 - Research Needs and related facilities-prepared by Prof. Prem Krishna, Roorkee University.
2. Doc.No. 2 - Deficiencies in present Indian Standards for Wind Loading - Prepared by Prof. Prem Krishna, Roorkee University.
3. Doc.No.3 - Scheme on Wind Engineering Study - Prepared by Indian Meteorological Department.
4. Doc.No.4 - Status of wind observation at Vishakha-patnam tower - prepared by Indian Meteorological Department.
5. Doc.No.5 - A Report on Departmental Activities in progress on Experimental Aerodynamics and Future Activities being planned in the Aeronautical Engineering Department, IIT Kharagpur - Prepared by Prof. B.C.Basu, IIT Kharagpur.

The Chairman welcomed the members particularly Prof. B.C. Basu, Head, Department of Aeronautical Engg., IIT Kharagpur, who has been co-opted to the Committee. He apprised the members that the subject "Wind Engineering" was also discussed by the concerned Working Group of the recently held meeting of the Indo-US Sub-Commission on Science & Technology alongwith mitigation aspect of Earthquake Hazard. The above Sub-Commission finally recommended that a second Indo-US workshop on Natural Disaster Mitigation (Earthquake and Wind Effect) Research should be organised in the

country which should give more stress on the wind engineering aspect. He also stated, that as the Committee has already done most of the work assigned to it, it should be possible to finalise the report at the next meeting. In this connection, he requested the concerned members to complete and finalise their respective contribution and notes whatever is pending with them.

Members discussed on the format of the report to be prepared. It was decided that the following additional notes also will be incorporated in the report.

1. A note from IMD describing the present status of wind observation in the country and what more should be done both as regards development of desired type of wind instruments and establishment of additional wind observing stations to suit the needs for engineering work including the funds required.
2. A note from NBO describing the present status of loss in terms of life and property incurred due to strong wind.
3. A note from the SERC giving the present status of their work on the kind of houses to be built to withstand high wind.

The Committee thereafter discussed the various documents and the deliberations are summarised as under :

Doc.No.1 - Research Needs and related facilities

The paper was discussed and it was decided that the following aspects of research studies could also be included in the document :

- (1) In order to minimise the effect of strong wind on various structures, cyclones shelters are being built at different places. The efficiency and behaviour of these cyclone shelters during actual cyclone situations need be studied in greater depth as an R & D programme.
- (2) It was noted that the Ministry of Agriculture is taking action to put up wind brakers along the coast by planting trees for reducing the damages. However, in view of the fact that due to pressure difference during cyclones, roofs of various structures are normally blown off, it was felt necessary to undertake some model study integrating into it both the effect e.g. wind force and pressure difference during a cyclone.
- (3) In view of the fact that orientation of buildings and structures with reference to wind flow is sometimes vital to avoid damage, it would be useful if wind tunnel study on different orientation of buildings and structures are taken up.

- (4) It was realised that rainfall in association with high wind cause frequently serious erosion of houses constructed with different materials. Study on the above aspect could also be planned.

Shri Mathur, NBO introduced an issue of the frequent damage caused by cyclones/tornadoes to street lighting system, telephone and electricity transmission lines. After a detailed discussion it was felt that if the existing ISI Code is strictly followed while erecting the above installations, which is not normally done by the implementing agencies, a lot of damage could be avoided. It was felt that if the detailed data of this type of damage is collected, changes in the Code provisions could be considered if necessary.

Shri S.K.Das, IMD commented on the proposal of enacting Legislation for allowing to put up instruments on all tall buildings and structures for making wind measurements. He said that it will be very difficult to implement such legislation as the buildings may belong to both Government and private parties. After a discussion it was agreed that at least authorities constructing tall buildings of height more than 75 m should be persuaded to permit research organisations to install instruments with, of course, an understanding that these will not in any way jeopardise the strength of the structures. SERC Madras and SERC Roorkee could be involved in the task. However, taking note of the fact that such legislation is in existence in some countries, the Committee decided to recommend that the DST may take up the matter with the Law Department to consider a similar legislation.

Prof. Basu, IIT Kharagpur stated that the annexure to one of the documents giving the list of wind tunnels and their present status is not exhaustive. Particulars of a few wind tunnels and specially a gust tunnel (generating sinusoidal gust) available at IIT Kharagpur is not included. Dr. Basu was requested to supply the detailed information of wind tunnels at IIT Kharagpur to Prof. Prem Krishna for incorporating the same in the document.

It was agreed that Prof. Prem Krishna will revise Doc.No.1 taking the above points into view.

Action : (Dr. Basu/Dr. Prem Krishna)

Doc.No.2 -

Deficiencies in present Indian Standards for Wind Loading

Members agreed generally with the points raised in the document. However, as regards holding workshops on "Code Practices", Shri Mathur stated that a regional training institute with UNDP assistance is being set up shortly by the NBO. After a discussion it was decided to recommend that NBO should organise workshops at suitable intervals of time to orient education in wind engineering aspects and also run a few courses on the subject. It was decided that the above aspects will be suitably incorporated in the note.

The Committee noted the IMD's proposal of setting up wind observation stations at 5 locations with instruments of the conventional type at 3 different heights at each location. However, the Committee felt that these instruments may not be able to record wind accurately at the maximum wind conditions during a cyclone, and they may not be able to withstand the highest wind. It was felt necessary that better type of wind measuring instruments should be developed in the country. For this purpose, one or two suitable instruments available abroad may be imported for study and development in accordance with our needs, and take up manufacture of the required number of instruments. It was decided that recommendation would be made for the development of suitable wind instruments.

Prof. G.N.V. Rao stated that, for wind engineering work, there is a need for putting up accelerometers with a response time of 2 sec. alongwith wind instruments at 3 different heights of various structures in the country to measure the magnitude and direction of wind and also the structural response. He also stated that the required expertise for the development of accelerometers exists at NAL Bangalore and VSSC Trivandrum. The need to measure gust and turbulence in various parts of the country was also felt by the Committee. After a discussion it was decided that Prof. Rao will finalise the technical specifications of accelerometers gust probe and turbulence probe and identify the institutions where these can be developed in consultation with Dr. Venkateswarlu and Prof. Prem Krishna.

Action: (Prof. C.N.V. Rao)

The Committee decided to recommend that SERC should select one specialised station as a test site and put up all the above instruments at three levels on a suitable tower. In this connection, it was suggested that efforts should be made to utilise TV towers at Madras for putting up the wind instruments. In this connection, Dr. Rakshit stated that on the basis of the decision at the last meeting of NTPC, Badarpur was contacted to make available their chimneys for putting up wind instruments. The response from NTPC was very encouraging. It was decided that Prof. G.N.V.Rao will prepare a proposal and send it to DST for taking up with NTPC.

Action : (Prof. G.N.V. Rao)

It was also decided that Dr. Venkateswarlu will prepare an R & D proposal for the development of appropriate wind measuring instruments suitable for cyclonic conditions and send it to Shri S.K.Das for incorporating it in IMD proposal to be revised.

Action : (Dr.Venkateswarlu)

The paper was discussed and it was decided that the contents will be taken into account by Dr. Venkateswarlu while suggesting a national programme for wind observations on tall towers at different heights.

Action : (Dr.Venkateswarlu)

Prof. Basu while presenting the paper gave brief summary of the work being done at IIT Kharagpur. He stated that IIT, Kharagpur has been receiving many requisitions from various institutions/users in the Eastern Regions to undertake model test of different structures in their tunnels. This work could not be taken up due to non-availability of a proper wind tunnel. While mentioning about the gust tunnel at IIT Kharagpur he stated that it can also be used as steady state wind tunnel but due to its small size, it cannot be utilised for industrial tests. In this context, he mentioned that IIT Kharagpur has been trying to set up an industrial wind tunnel for sometime past to cater to the needs of users in the eastern region which is affected frequently by cyclones and tornadoes. After a discussion it was decided that the additional information on research needs and related needs of wind tunnel etc. as contained in the above document will be taken note of by Prof. Prem Krishna while revising the paper on "Research needs and related facilities".

Action : (Prof.Prem Krishna)

The Committee discussed at length on the various aspects of research needs in the field of wind engineering like model studies, field studies, instrument development and model experiments on industrial structures in wind tunnels. It was decided to recommend that for the size of our country and in view of the extent of damages caused to various structures due to high wind there should be at least 3 industrial wind tunnels in the country to cater to the needs of each region. Keeping in view the existence of expertise and infrastructure facilities the Committee decided to recommend setting up of three tunnels, one each at IISc Bangalore, Roorkee University and IIT., Kharagpur.

The Committee noted that the next World Conference on Wind Engineering will be held in 1987. Members felt that because of the importance of the subject to India we should host the above conference in order to activate interest more speedily right from now. In this connection, Shri Mathur informed the members that a decision on the venue of the next conference will be taken at the forthcoming meeting of the United Nations Committee on Housing and Settlement to be held in Nairobi sometime in March-April 1982. It was decided to recommend that DST should sponsor and take initiative for holding the International Conference in India in 1987. As the proposal has to be put up at the forthcoming

conference in Nairobi it was decided that Prof. Jai Krishna would suggest to Secretary DST to sponsor the conference and communicate the decision to the leader of the Indian Delegation who will be attending the above UN Conference at Nairobi.

The Committee discussed the availability of expertise in the development of the industrial wind tunnels in the country. Noting that during the last decade USA and Japan developed many sophisticated wind tunnels it was decided to recommend to send a team of experts to USA for looking at different wind tunnels in that country for technological feedback so that the wind tunnels could be developed in India on modern lines without delay.

It was also noted that the International Council on Building Research will discuss many aspects of wind engineering. It was felt that it would be appropriate if a meeting of the above Council could be held in India. In addition, it was also decided to recommend that a delegation should be sent to participate at the Council Meeting wherever it is held.

It was decided that the concerned members will finalise their respective chapters and forward to DST latest by 1st March 1982. The Member Secretary, Dr. Rakshit will prepare a draft report and circulate to members by the end of March 1982. It was also decided that the last and final meeting of the Committee will be held in April 1982 at Bangalore or Roorkee if feasible.

The meeting ended with a vote of thanks to the Chair.



Annexure A₃

NOTE ON STRUCTURAL DAMAGE DUE TO CYCLONE IN ANDHRA PRADESH

INTRODUCTION

Within a span of two weeks in the month of November 1977, the east coast of South India was hit by two severe cyclonic storm one on the 12th and the other on the 19th. The latter, which was considered to be the most severe storm in over a century, had devastated the coastal regions of Krishna, Guntur and Prakasam districts in Andhra Pradesh. It took its origin in the Bay of Bengal and travelled for two days changing its direction from time to time, and threatening to strike the coast anywhere from Nagapattinam and Vishakhapatnam. Finally it crossed the coast at the northern border of Prakasam District.

In addition to the cyclone, a tidal wave of about five metres height severally hit the Divi and Bandar taluks of Krishna District. The residents of these two taluks were the worst affected as they had to fight with the ferocious tidal wave and protect themselves from the fury of the sudden storm sweeping across a vast area. A total area of about three hundred square kilometers in this fertile and densely-populated delta region was inundated by saline water due to the tidal wave.

Thousands of families in the cyclone-affected area were rendered homeless and suffered untold misery. Nearly forty thousand people are reported to have lost their lives. Myriads of birds, cattle and other living beings were lost in the tidal water and stormy winds. A large number of cabled roof sheds covered with asbestos sheets, G.I. sheets, and Mangalore tiles were rared to the ground. Almost every thatched roof was blown off. A large number of industrial sheds in and around Vijaya-wada and Guntur towns totally collapsed. Gales of velocity upto about 200 km per hour were estimated during the period of the cyclone. Loss of property due to the cyclone and damage to buildings and crops were maximum in Guntur and Prakasam districts while the loss of life due to tidal wave was very heavy in Krishna district. The tidal wave which engulfed about 120 villages with a population of over 90,000 in Divi and Bandar taluks accounted for more than eighty percent of the total lives lost in the entire area affected by the cyclone.

Transport and communications, power and water supply were severely affected in this area for a period of about one month. Most of the transmission line poles along the railway lines and highways in the cyclone affected area were damaged to an irreparable extent.

The damage caused by the cyclone to the various structures was examined by the scientists of the Structural Engineering Research Centre, Madras, during their visits to the cyclone affected areas in the first and last week of December 1977. A report on the Structural damage has been prepared by SERC, Madras for publication. A few of the typical cases of structural failures extracted from the report are given below.

(i) Industrial and Residential Buildings

The roof cladding sheets of many buildings were blown off due to the failure of J-bolts. The lack of lateral bracing between trusses led to the collapse of many industrial sheds. Tearing of rolling shutters, flange and web plates of steel girders and stanchions, bending and twisting of heavy columns supporting the roof structure, buckling of base plates and yielding of foundation anchor bolts have been observed as the common failure in the collapsed structures.

The main workshop building for the Metallurgical department of the Government Polytechnic at Vijayawada had severe damage due to the cyclone. The A.C. sheets of the roof were blown off due to the failure of J-bolts. The corrugated steel rolling shutter was torn off and the pieces were thrown into the building.

Two sheds were constructed on Eluru road in Vijayawada for a Brick Industry. One of the sheds housed a brick kiln and was covered with A.C. sheets. The supporting structure of the roof suffered major damage due to heavy wind ward thrust and the roof cladding was blown off due to leeward suction.

A large steel framed structure was under construction during the cyclone period for the thermal power station at Ibrahim Patnam in Vijaywada. The structure is located near a valley between two large hills, and this topography might have intensified the damage by the inrush of gale and resulted in complete wreckage of the gigantic structure. The columns of the structure were temporarily braced with bolted connections. It was reported that the columns were awaying for quite a long time during the period of cyclone and the temporary connections were completely damaged under the intensive dynamic forces.

An Agro-Steel Complex with A.C. sheet roofed sheds was constructed in the hilly terrain between Vijayawada and Guntur. The structure constructed with steel tubular trusses over columns of I-sections, suffered extensive damage due to failure of J-bolts and insufficient column section. Some of the columns failed due to buckling of the base plate.

A shed to house a steel rolling mill was constructed on the Vijayawada-Guntur highway. It was covered with A.C. Sheet roof. The trusses were supported over steel stanchions made up of two I-sections. Although the supporting columns and the base plate were strong enough to withstand the gusty winds, the entire structure collapsed due to yielding of anchor bolts.

(2) Residential buildings

Several residential houses with a combination of flat and sloped roof were constructed by the Public Works Department for the industrial labour in Vijayawada. The failure of these houses clearly revealed how vulnerable the sloped roofs were in cyclone prone area when compared to the flat roofs.

In a colony of sixty houses constructed at Harijanawada (Jayapuram) by the side of the Avanigadda-Kodur road in Krishna district, the roof sheets were blown off while the wooden trusses and the walls were left undamaged.

(3) Towers and transmission line poles

Two steel towers, each of 120m height, erected for the All India Radio Station at Nambur near Vijayawada were damaged due to failure of guy wires. One of the towers toppled completely while the other failed at one third of its height. The tubular members of the tower very badly buckled.

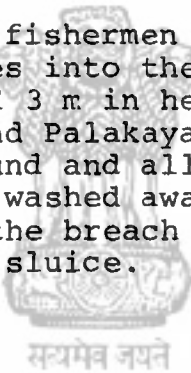
Almost every power line and communication line was cut off due to the failure of poles and towers. All the prestressed and the reinforced concrete poles failed at their bases and were lying on the ground. Most of the electric poles were twisted and bent to an irreparable extent. Due to short supply of new poles, they were rebent to quickly commission the power line in vital areas.

(4) Other structures

So far typical failures of industrial structures have been dealt in some detail. In addition to these, there were several other structures which were destroyed by the storms and tidal wave. A brief account of these failure is given in this section.

A reinforced concrete chimney of 36m height and 90m diameter constructed in Guntur has completely failed at the junction of its base and the horizontal chute and fell on the Guntur-Vijayawada highway. Although its collapse was attributed to an 'act of God', a close look at the failure surface revealed several design and construction defects. Lumps of mortar without any coarse aggregate and honeycombs which were noticed in the failure region, were a clear proof of inadequate reinforcement at the failure section was stressed to its plastic deformation and failed with a typical neck and cup fracture of tension break.

Palakayathippa is a fishermen village where a branch of the Krishna river merges into the Bay of Bengal. A tank bund of 8 km in length and 3 m in height was constructed to protect the villages around Palakayathippa. The rushing tidal wave breached the bund and all the villages on the banks are reported to have been washed away. The relative levels of bund before and after the breach may be observed from the road level on the outfall sluice.



Annexure A₄

Information received regarding the recommendation
pertaining to "Effect of Wind on Common man's dwellings"
from various department/agencies in the country.

(Prepared by NBO, New Delhi)

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S.No.	Name of the department/ Organisation	Action taken
1.	Andhra Pradesh Housing Board Hyderabad.	Andhra Pradesh Housing Board has not taken up any massive Housing Scheme in and around the wind affected (cyclonic) area of Andhra Pradesh state so as to develop any remedial measures.
2.	Rural Housing Wing, NBO, Trivandrum	The Wing informs that Kerala is free from the occurrence of any cyclonic storms in the past. No special precautions are therefore taken with regard to cyclonic storms. Even though moderately high winds prevail along the coastal regions, they are not of an intensity to cause any serious damage to buildings. The main cause of damage along the coastal belt is sea erosion in certain areas.
3.	Central Building Research Institute, Roorkee (UP)	The Institute has intimated that they have not constructed any home to withstand destructive action of wind like cyclone etc. However, some work has been under taken on cyclone shelter after the occurrence of last year's disastrous cyclone in Andhra Coast. A few conceptual plans have been developed by the Institute.
4.	School of Planning and Architecture, New Delhi	The following two studies have been conducted by the School of Planning and Architecture : a) A very useful study in respect of the wind effect on common man's dwellings was conducted in 1977 by the School of Planning and Architecture in Divi Seema area of Andhra Pradesh and its report entitled "CYCLONE AND BUILDINGS BEHAVIOUR" has already been published.

b) A paper entitled "THE COROMANDEL COASTAL AUTHORITY FOR BUILDING AGAINST CYCLONE" by Professor S.K. Narayana and Ms.Nalini Thakur of the School of Planning and Architecture was published in the School Journal "Urban and Rural Planning Thought" (Volume XXI No.1, 2nd January-June 1978 pp. 60-67).

NBO Liaison Cell, Calcutta

The NBO Liaison Cell stationed at Calcutta has forwarded the result of studies undertaken by the Cell on "Effect of wind on Common man's dwellings" in rural areas of this zone. This also applies to slums and urban housing for the poorest section of the city dwellers. It was experienced that houses built with the precautions incorporated in the above report stood better against the hazards of cyclones. The Liaison Officer has suggested some points regarding preparation of necessary literature covering do's and don't's with adequate sketches for adoption of the said techniques on a wider adoption in the Eastern Region.

Department of Earthquake Engineering, University of Roorkee, Roorkee (UP)

The Department has brought out a very useful report on "Effect of Cyclones on Structures with Special reference to Vishakhapatnam Steel Plant."

Punjab Housing Development Board, Chandigarh.

The Board has intimated that Punjab does not lie in the region prone to devastating cyclones and storms.

Rural Housing Wing, Srinagar

State of J & K does not experience cyclones and winds of devastating nature, as such no specific design and construction features to guard against this eventuality are required for construction of houses in this region.

Rural Housing Wing, Chandigarh.

The Wing has contacted concerned departments/agencies of the State Govts. under its jurisdiction. The replies received from the Chandigarh Housing Board and the Chief Engineer PWD(B&R), Himachal Pradesh indicate that they have not undertaken any specific housing project in this respective areas to withstand the destructive action of abnormal wind forces. The Chief Engineer, PWD(B&R)

(Himachal Pradesh) has however, informed that they are following provisions stipulated in IS Code 875 ... 1964 in respect of wind load for design of various buildings in the State.

10. NBO Housing Wing,
Vallabh Vidyanagar

The Wing approached various authorities connected with the housing under its jurisdiction which includes the states of Gujarat, Maharashtra and Madhya Pradesh. It has been observed that no special measures are taken in Construction of Houses in the Region. Only parapet walls are provided on the roof top to secure the roof.



सत्यमेव जयते

NOTE ON IT STANDARD ON WIND LOADING PREPARED BY THE ISI

Status of Topics (according to Table 10.1 of "WIND FORCES IN ENGINEERING" 2nd Edn by Peter Sachs) covered in IS:875-1964 Code of Practice for Structural Safety of Buildings: Loading Standards (Revised)

1.1 Wind Speed Regions:- The wind pressure given in Fig 1A are the maximum ever likely to occur in any locality including conditions of winds of short durations, meaning thereby winds in which the maximum speed is attained suddenly and lasts for a few minutes only, such as in squalls. The response of a structure to wind pressure depends not only on its own characteristics and those of the wind flow but also on the duration of the wind pressures. Certain structures may not respond to short lived phenomena of wind, such as given in Fig 1B (see p.) need only be taken into consideration

The relationship between wind pressure and velocity is $p = KV^2$ when p is the pressure, V the velocity and K is a coefficient. the value of which depends on a number of factors, such as the wind speed, the proportion and shape of structure and the temperature of air. In the preparation of this basic wind pressure map, a value of 0.006 has been assumed for K and P is expressed in kg/m^2 and V in km/h .

1.2 Topographical Factors - Not covered.

1.3 Wind Variation with Height - The basic wind pressure for the zones shown in the map shall be given below:

Pressure in kg/m^2 upto a height of 30 m above the Mean Retarding Surface	Pressure in kg/m^2 at a Height (Expressed in Metres) of									
	35	40	45	50	60	70	80	100	120	150
100	104	105	108	111	115	118	122	127	132	138
150	156	158	163	167	172	177	183	191	198	207
200	208	210	217	222	230	236	244	254	264	276

(For intermediate heights interpolated values may be adopted)

1.4 Ice and Snow Loads- If a roof is subjected to snow load, it should be designed for the actual load due to snow or for the live loads specified in Table II whichever is more severe. Actual load

due to snow till depend upon the shape of the roof and its capacity to retain the snow and each case shall be treated on its own merits.

In the absence of any specific information, the loading due to the collection of snow may be assumed to be 2.5 kg/m^2 per cm depth of snow. The possibility of total or partial snow load should be considered, that is one half of the roof fully loaded with the design snow load. In the case of roofs with slopes greater than 50° , snow load may be disregarded, where, however, there are possibilities of formation of snow pockets, these should be taken into account.

1.5 Gust Effects - The wind velocities recorded at any locality are extremely variable and in addition to steady wind at any time, there are effects of gusts which may last for a few seconds. These gusts cause increase in air pressure but their effect on the stability of the building may not be quite important; often gusts affect only part of the building and the increased local pressures may be outbalanced by a momentary reduction in the pressure elsewhere. Because of the inertia of the building, short period gusts may not cause any appreciable increase in stress in the main components of the building, although the walls, panels and the roof sheetings may be more seriously affected.

1.6 Shape Factors - For structures of various plan shapes other than rectangular plan shape, the external pressures acting on the projected area in the plane perpendicular to the wind, shall be the product of basic pressure as given in 4.2 and the factors given in Table III.

TABLE III SHAPE (IN PLAN) FACTORS

Plan Shape of the Structure	Factor		
	Ratio of Height to Base Width 0-4	Ratio of Height to Base Width 4-8	Ratio of Height to Base Width 8 or over
Circular	0.7	0.7	0.7
Octagonal	0.8	0.9	1.0
Square (wind perpendicular to diagonal)	0.8	0.9	1.0
Square (wind perpendicular to face)	1.0	1.15	1.3

NOTE 1 - In the case of projections above the general roof level, the base width shall be taken as the width of the construction where it rises from the surface of the roof; and the height governing the ratio of height of base width shall be that from the roof surface to the top of the construction.

NOTE 2 - The division of wind load into that acting on windward and leeward sides shall be the same as that for rectangular buildings as affected by the openings.

1.7 Pressure Coefficients

4.5 Wind Pressure on Walls

4.5.1 Basic Components of Wind Pressure - The external wind pressure acting on a wall which is perpendicular to the assumed direction of wind may be considered as consisting of two parts, corresponding to an average position pressure of $0.5 p$ on the windward face and an average suction of $0.5 p$ on the leeward face. A wall, which is exposed to wind on both its faces, would therefore be subjected to a total average pressure of p acting in the direction of the wind.

4.5.2 Total Pressures - When the walls form an enclosure there will be a positive pressure of $0.5 p$ on the windward wall and a suction of $0.5 p$ on the leeward wall in addition to the internal air pressures as given in 4.3.5. Thus, a wall of any building should be sufficiently strong to resist a total average pressure, outwards or inwards, of :

$0.5 p$ for buildings having a small degree of permeability (see 4.3.5.1);

$0.7 p$ for buildings of normal permeability (see 4.3.5.2 and

p for buildings with large openings (see 4.3.5.3) a for walls exposed to wind on both faces.

4.5.3 Local Effects - The pressures and suction specified in 4.5.2 are average values and they may exceed locally. In designing individual wall panels and wall sheeting, due account of these local effects shall be taken by increasing the values specified in 4.5.2 by $0.1 p$.

1.8 Shielding Effect - In multi-span roofs in which the spans heights and slopes are approximately equal and where the windward span gives shelter to the succeeding spans, the spans being adjacent, the following external pressures may be taken in making the general stability calculations and in the design of the framework (see Fig 12).

- a) On the windward slope of the windward span and the leeward slope of the leeward span, the pressure appropriate to the slopes as given in Table IV.
- b) On all other roof slopes, account need be taken of only the effect of wind drag (see 4.4.4).

NOTE - However, each span has to be designed for the same wind pressure for which it would have been designed, had there been only one span.

1.9 Buildings, Roofs and Cladding

4.3.1 The effect of wind shall be calculated on the basis of basic pressure given in 4.2 for the entire height of the building, and any projections thereof, having due regard to the level of mean retarding surface and variation in wind pressure with height. In making the calculations, due regard shall also be given to shape factors (see 4.3.2) and interval air pressures (see 4.3.5)

4.3.3 The stability calculations of the buildings as a whole shall be done considering the combined effect, as well as separate effects of imposed loads and wind loads on vertical surfaces, roofs and any other part of the building above the general roof level.

4.3.4 Calculations shall be made for the effect of wind on the design of individual components of the building. Where, however, adequate stiffening is provided by walls, or floors and walls, calculations for the effects of wind, except in regard to wall panels, roofs and foundations, need not be made on:

- a) a building or a part of a building, of which the height 'h' does not exceed twice the effective widths (see Fig 2A, 2 B and 2C).
- b) a section adjoining two parts of an adequately stiffened building, if height of the section exceeds twice its width but the length of the section does not exceed four times its width (see Fig 2D).
- c) a wing of such a building if it does not project more than twice its own width (see Fig 2E).

4.3.5 Internal Air Pressure - Internal air pressure in a building depends upon the degree of permeability of the cladding to the flow of air. The internal air pressure may be positive or negative, that is, a positive pressure or suction, depending on the direction of flow of air in relation to the openings in the building. In practice, the four cases given in 4.3.5.1. to 4.3.5.4 may be considered.

4.3.5.1 Buildings having a small degree of permeability - Buildings where the cladding is such that the flow of air through the cladding is practically negligible, such as multi-storey buildings with panelled walls and no openings, the internal air pressure may be neglected.

4.3.5.2 Buildings of normal permeability - Buildings where the cladding permits the flow of air but where there are no large openings, an internal positive pressure or suction of $0.2 p$ acting normal to the wall and roof surface, shall be considered in addition to the external wind pressures (see Fig 3 and 4)

NOTE - The term normal permeability relates to the flow of air commonly afforded by the claddings not only through the open windows and doors, but also through the slits round the closed windows and doors through chimneys, ventilators and through the joints between roof coverings.

4.3.5.3 Buildings with large openings - Buildings with large openings, that is, openings larger than 20 percent of the wall area, such as hangars and sheds, an internal positive pressure or suction of $0.5 p$ acting normal to the wall and roof surfaces shall be considered in addition to the external wind pressures (see Fig 5).

Buildings with one open side may be assumed to be subjected to internal positive pressure or suction similar to those for buildings with large openings.

4.3.5.4 Buildings of open type - Buildings with roofs but no walls, the roofs will be subjected to pressures from both inside and outside and the recommendations given in 4.6.1.2 shall be followed.

4.6 Wind Pressure on Roofs - The design wind pressure on roofs shall be determined as the resultant effect of average external wind pressure as given in 4.6.1 and the internal air pressure in the building as given in 4.3.5. Since the algebraic sum of the values determined from 4.6.1 and 4.3.5 represent average values of the positive pressures or suction on the roofs due consideration should also be given to local affects as given in 4.6.2.

- 1.10 Cross Wind Effects - Not covered.
- 1.11 Chimneys, Tanks etc - Provisions at 1.6 applicable here also.
- 1.12 Towers, Masts and Trusses - Only trusses have been covered.

4.4.1 Wind loads which should be considered in the design of structural framework, such as rigid frame, trusses resting on walls and columns shall be those transmitted to it by the members and/or components supported on it including the wind pressures which might be directly acting on the framework.

4.4.2 In arriving at the wind loads, only the average values of pressures as indicated in 4.5.2 for walls and 4.6 for roofs need be considered and no account need be taken of the local effects.

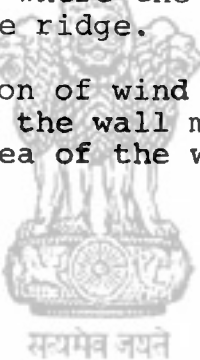
4.4.3 The resultant wind loading on a structural framework shall be arrived at on the basis of the average values of pressure simultaneously acting on the structure having due regard to the direction of wind. Thus, for example, when a total pressure of $0.7 p$ is being considered on the windward cladding, the corresponding wind load on the leeward cladding should be $0.3 p$ and vice-versa.

4.4.4 Wind Drag

4.4.4.1. The effect of wind drag on roofs may be taken at

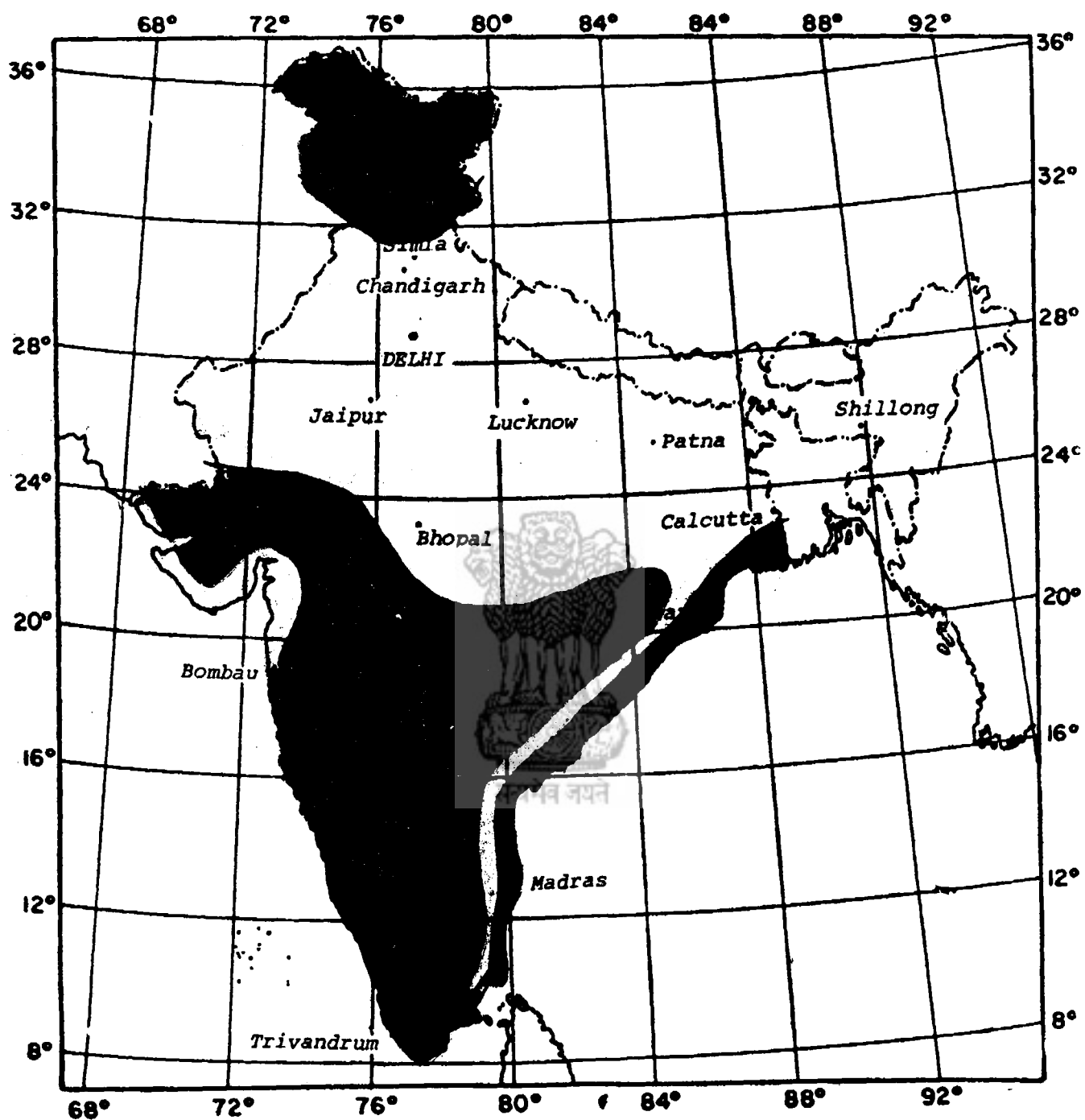
- a) $0.05 p$ measured on the plan area of roof where the direction of wind is normal to the ridge.
- b) $0.025 p$ measured on the total area of roof ignoring openings where the direction of wind is parallel to the ridge.

4.4.4.2 Where the direction of wind is parallel to a wall the effect of wind drag on the wall may be taken at $0.025 p$ measured on the total area of the wall ignoring openings.





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The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.

Fig. 1A Basic Maximum Wind Pressure Map of India Including Winds of Short Duration.



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NOTE 1 - For purposes of this map, a short duration wind is that which lasts only for a few minutes, generally less than 5 minutes.

NOTE 2 - The relationship between wind pressure and velocity is $p = KV^2$ where p is the pressure, V the velocity and K is a coefficient, the value of which depends on a number of factors, such as the wind speed, the type, proportion and shape of structure and the temperature of air. In the preparation of this basic wind pressure with map, a value of 0.006 has been assumed for K and p is expressed in kg/m^2 and V in km/h .

NOTE 3 - The basic wind pressures for the zones shown in the map shall be as given below :

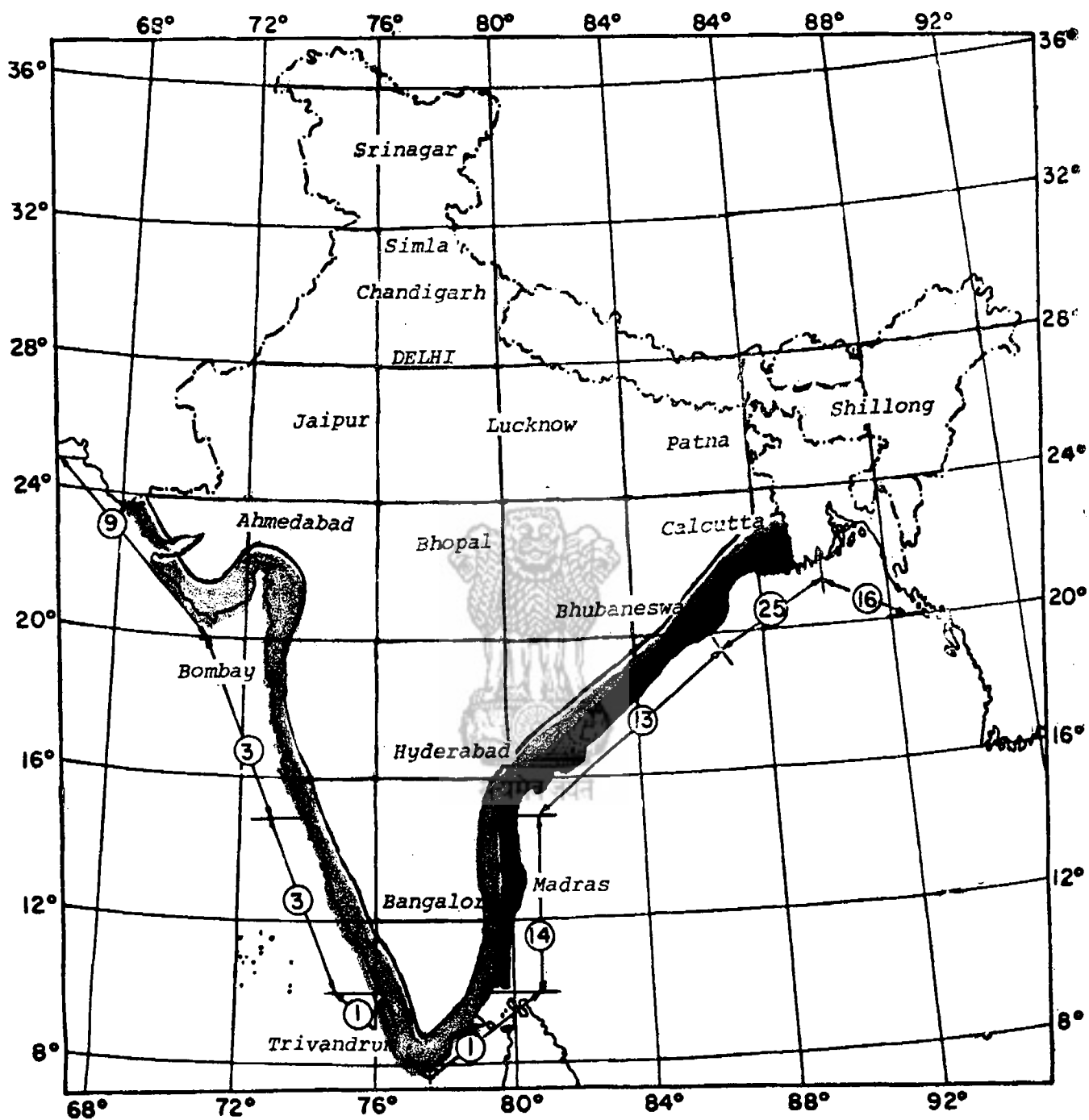
ZONE	PRESSURES In Kg/m^2 UPTO A HEIGHT OF 30m ABOVE THE MAIN RETARDING SURFACE	PRESSURES IN kg/m^2 AT A HEIGHT (EXPRESSED IN METERS) OF									
		35	40	45	50	60	70	80	100	120	150
	100	104	105	108	111	115	118	122	127	132	138
	150	156	158	163	167	172	177	183	191	198	207
	200	208	210	217	222	230	236	244	254	264	276

(For intermediate heights interpolated values may be adopted)

NOTE 4 - The basic wind pressures indicated above are the maximum ever likely to occur in the respective areas, under fully exposed conditions. In the case of mountainous areas, the values indicated above should be modified according to the local conditions because the surface wind is known to depend markedly on the local topography etc.



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The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.

Fig. 1B Basic Maximum Wind Pressure Map of India Excluding Winds of Short Duration.



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NOTE 1 - For purposes of this map, a short duration wind is that which lasts only for a few minutes, generally less than 5 minutes.

NOTE 2 - The relationship between wind pressure and velocity is $p = KV^2$ where p is the pressure, V the velocity and K is a coefficient, the value of which depends on a number of factors such as the wind speed, the type, proportion and shape of structure and the temperature of air. In the preparation of this basic wind pressure map, a value of 0.006 has been assumed for K and P is expressed in kg/m^2 and V in km/h .

NOTE 3 - The basic wind pressures for the zones shown in the map shall be as given below :

ZONE	PRESSURE IN kg/m^2 UP TO A HEIGHT OF 30 m ABOVE THE MEAN RETARDING SURFACE	PRESSURE IN kg/m^2 AT A HEIGHT (EXPRESSED IN METERS) OF									
		35	40	45	50	60	70	80	100	120	150
	60	62	63	65	67	69	71	73	76	79	83
	100	104	105	108	111	115	118	122	127	132	138
	150	156	158	163	167	172	177	183	191	198	207
	200	208	210	217	222	230	236	244	254	264	276

(For intermediate heights interpolated values may be adopted)

NOTE 4 - The number of severe cyclones which have approached or crossed the coasts during 1891 to 1960 is indicated in circles in 5° latitude zones. (A severe cyclone is one in which the wind speed exceeds $89 km/h$ corresponding to a wind pressure of $48 kg/m^2$). The influence of a severe cyclone may be taken to extend from the coast line up to the line demarcating $60 kg/m^2$ zone.

NOTE 5 - The basic wind pressures indicated in the map are the maximum ever likely to occur in the respective areas, under fully exposed conditions. In case of mountainous areas, the values indicated above should be modified according to the local conditions because the surface wind is known to depend markedly on the local topography, etc.



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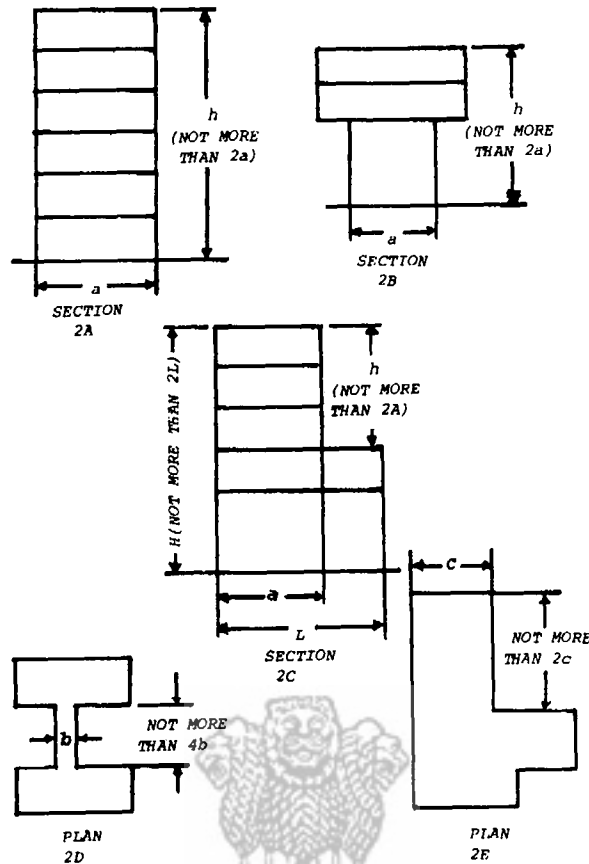


Fig.2 DIAGRAM ILLUSTRATING LIMITING PROPORTIONS FOR WHICH NO GENERAL STABILITY CALCULATIONS NEED BE MADE WHILE CONSIDERING WIND LOAD

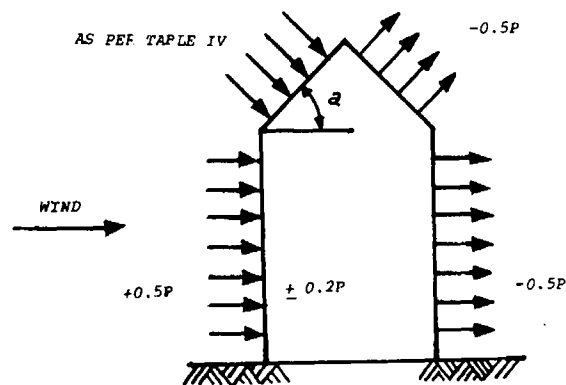


Fig.3 BUILDING WITH GABLE ROOF AND NORMAL PERMEABILITY



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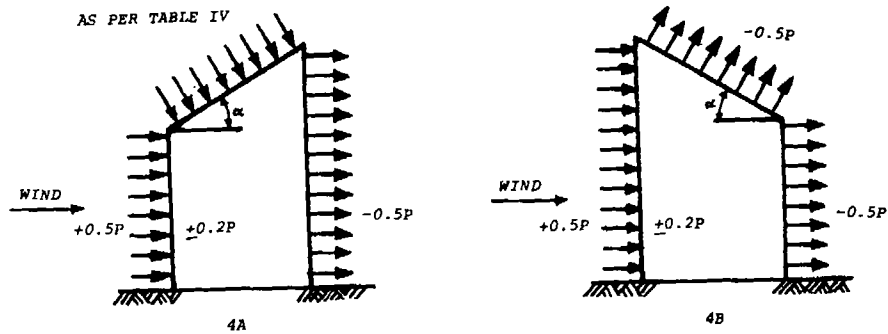


Fig.4 BUILDING WITH LEAN-TO-ROOF AND NORMAL PERMEABILITY

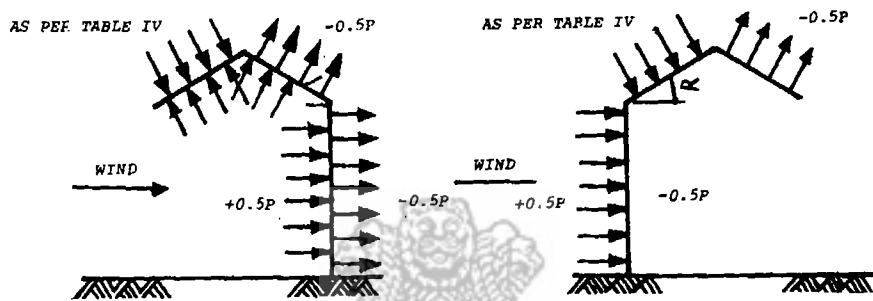


Fig.5 BUILDING OPEN ON ONE SIDE OR WITH LARGE OPENING ON ONE SIDE

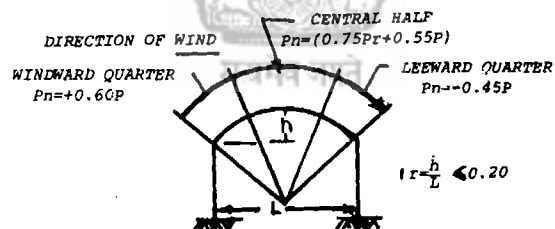


FIG.6

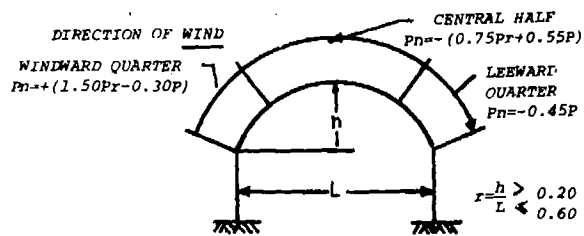


FIG.7



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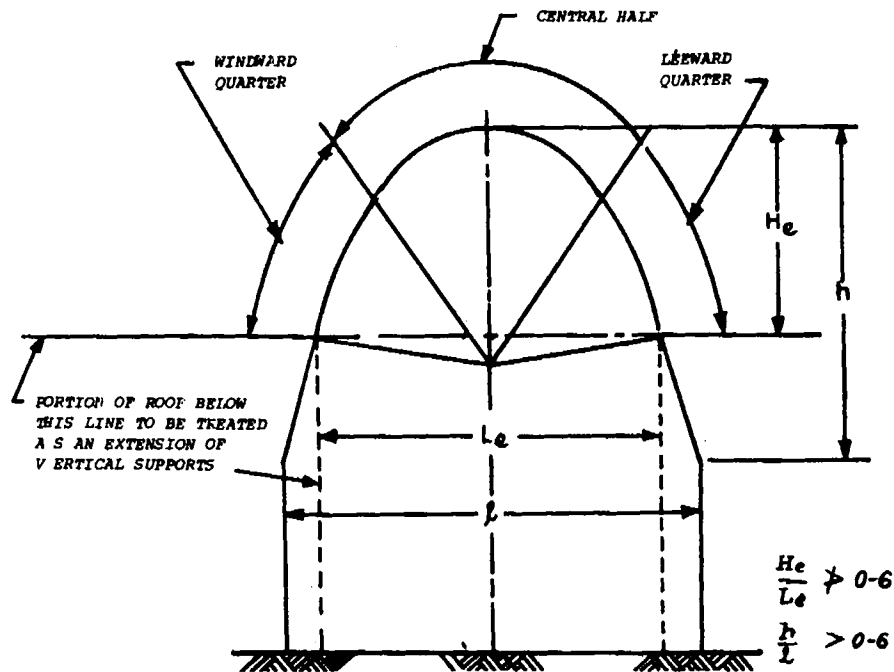


FIG. 8

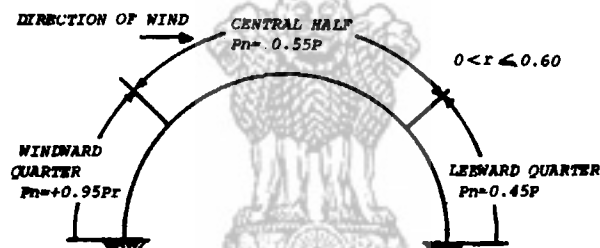


FIG. 9

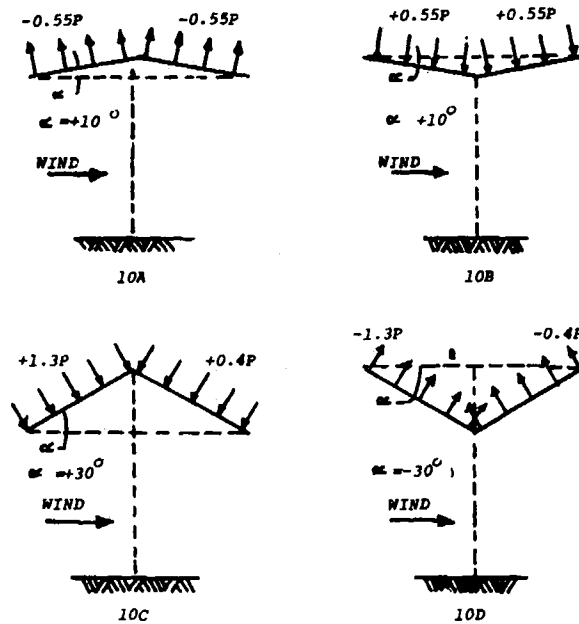


FIG. 10 BUTTERFLY TYPE STRUCTURES



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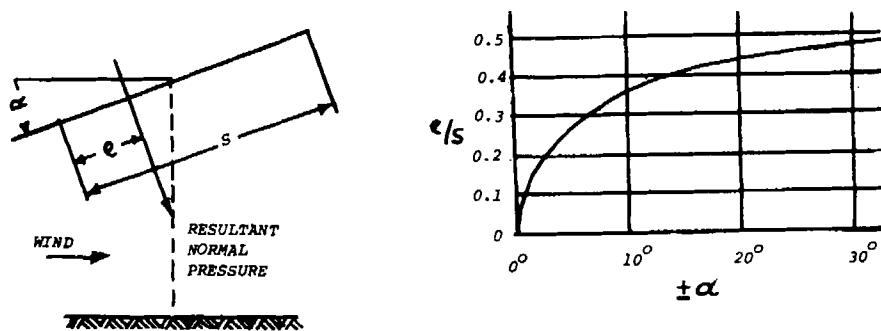


FIG.11 INDEPENDENTLY STANDING LEAN-TO-ROOF

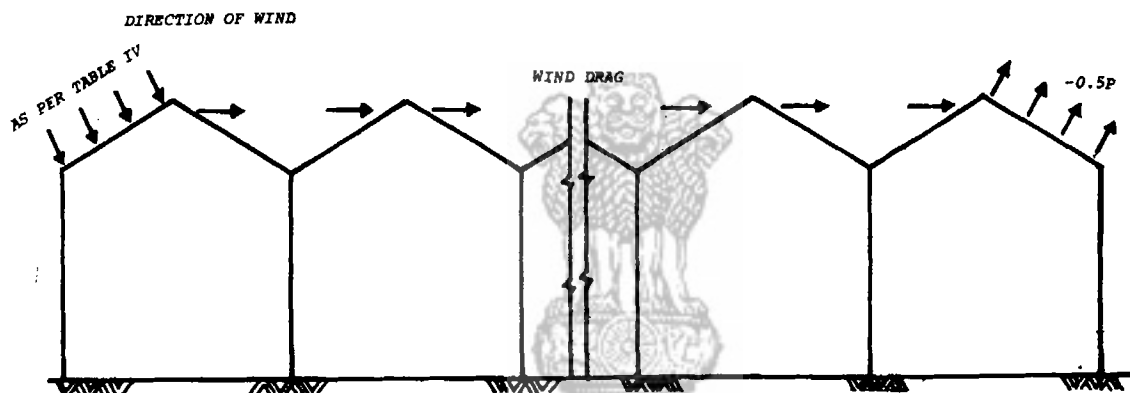


FIG.12 EXTERNAL WIND FORCE ON MULTI-SPAN ROOFS.



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Background Paper for the First Committee Meeting

Prepared by the IMD

<u>Present observation arrangements of wind</u>	<u>Levels of observations</u>	<u>No. of stations in India</u>
i) Autographic records of wind	8-10	70
ii) Continuous measurement on wind over tower.	2,4,8,16,32,48 and 64m a.g.l.	1
iii) Upper wind	.15m, .3, .6, .9,	
a. Pilot Balloon	1.5m and so on	62
b. Radio wind and Radar wind	-do-	32

Future Installation
Necessary to obtain
required data.

The data required are vertical profiles of wind and temperature to as high an altitude as possible, and measures of turbulence (Gustiness).

Pilot Balloon data are not suitable for wind Engineering. Tower instruments are appropriate under all weather conditions. When the winds are not strong Kytoons may be used. In the beginning it is suggested that all TV towers in the country be provided with wind and temperature sensors. At the same stations, Kytoons may be used to obtain winds at levels above the tower height.

The parameters to be measured are temperature, wind speed and wind director. Temperature upto 0.1°C, wind speed to 0.5m/s, wind direction to 5° are required. Wind may be measured by photoelectric or electrical contact cup anemometers at logarithmic intervals of height, but temperature by thermistors or Platinum resistance thermometers (Shielded and aspirated) can be measured at larger linear intervals. Turbulence parameters may be measured at one level sufficiently high to avoid ground effects. Sonic Anemometer/Thermometer is an appropriate equipment for this purpose.

Are such additional instruments available commercially?

Not available in India. They are to be imported.

What order of costs are involved.

1. Wind speed, wind direction, temperature sensor with cable, recorder and charts.

1.5 lakhs each (F.E)

Kaytoons - 2 Lakhs each (Indian)

2. Sonic anemometer 1 set with all accessories. 2 Lakhs (F.E)

Can such equipment be developed in our country.

Not currently available in India Meteorological Department to increase production of conventional equipment or design the equipment.



SCHEME OF WIND ENGINEERING STUDY - Prepared by the IMD.1. Introduction :

The problem of wind effect mitigation on structures and buildings during high wind associated with cyclonic storms, tornadoes etc. were discussed at different forums and relevant studies are being made in different universities, institutes and national laboratories. In order to make the present research effort more effective and useful there is a necessity to look at the total aspect of research effort being made in different institutions and universities, identify the gaps both in terms of infrastructure and equipment facility so that R & D programme could be suggested. To formulate and coordinate future R & D programme in this area a Wind Engineering Council has been set up in the country under the sponsorship of Department of Science & Technology of Government of India. During the first meeting of this committee, after a detailed discussion, it was felt that though the wind information from the existing network of wind observatory of IMD provides very useful information for wind engineering study, sophisticated wind measuring devices are to be introduced in the country to collect data as required by Wind Engineers particularly to study the effect of gusts on structures. While the need for wind data of maximum wind speed during cyclones, tornadoes etc. were well realised, it is felt that the wind data of different levels upto 300 metres from the ground level would also be required very much for wind engineering problems. In this connection, the possibility of wind observations from existing tall towers was discussed in the meeting. In this context, it is stated that a set of instruments has recently been installed at several levels on a 65 M special tower at Vizag and the data are being collected and analysed. It was suggested to utilise more towers of Vizag type for obtaining wind observations.

During the Second meeting of Wind Engineering Committee held under the sponsorship of Department of Science and Technology, it has been decided to start three stations along east coast, one station at Saurashtra coast and another at Delhi to collect wind and temperature data at 10 metre, 25 metre and 50 metre levels above ground. This scheme is envisaged to collect maximum wind speed data during gusts for structural designing. The data collected would also be analysed by this Department. The accuracy of the instruments required to be installed for this purpose, should be 0.1° C for temperature, 0.5 m/sec (1 knot) for wind speed and 5 deg. for wind directions.

2. Objectives for the scheme :

Since the requirement is to ensure continuous recording of wind data including winds of gale force at times associated with cyclonic storms, it is essential that no part of the instrumentation should suffer any mechanical failure particularly during very high winds. We have therefore to ensure that the

systems is rugged enough to withstand high winds and it should continue to record the data without failures. Considering the above requirements, a mechanical system like the Dines PT Anemograph would have been ideal for this purpose but it is not suitable for installation at different levels on 50 M tower. The only alternative, therefore, is to equip the towers with electrical cum mechanical types of instruments. To get the accuracy of 0.1°C for temperature, 0.5 m/sec for wind speed and 5 deg for wind direction as envisaged above with scheme, special types of instruments have to be developed and considerable effort have to be made on R & D work to obtain instruments having these accuracies. Sophisticated instruments available at present with the above accuracies, like hot-wire anemometers etc are only meant for short period observations and they require very frequent on the spot calibration. It is also necessary to have different sets of equipment to cover all ranges of temperatures and wind that are likely to be encountered. To leave a good resolution in the chart consistent with the accuracies the recording chart has to be driven very fast. Since our requirement is to ensure continued recording of wind and temperature including cyclonic winds, it is proposed to use our usual conventional electrical instruments like generator type Anemometers, electrical wind vanes and thermistor type temperature recorders which are quite rugged and proved their sturdiness and stability in holding the calibration in years of their use in the Department. Therefore, this project report for equipping five stations with our usual conventional equipment for collecting temperature and wind data at three levels above ground on 50 metre towers is prepared on the following lines for submission to the Department of Science & Technology to undertake the scheme on Wind Engineering.

3. Equipment:

The instrument envisaged for collecting wind data is the IMD electrical anemograph. This is an instrument for remote recording of the instantaneous values of wind speed and direction as well as the various gust parameters viz. the gust peak speed, minimum speed and the gust formation and duration time. This consists of a Cup generator anemometer for the measurement of wind speed, a Selsyn Windvane for the measurement of wind direction, a wind speed recorder with a range 0 to 100 Knots and reading accuracy of 1 Knot (about 50 amper) and a wind direction recorder with a range 360° -50- 360° corresponding to two vane rotations and a reading accuracy of $7\frac{1}{2}$ degrees.

The Cup Generator Anemometer proposed to be used for the measurement of wind speed has a time constant of the order of 0.2 seconds around 35 Kt and a starting speed of 2 Kt. Since the scheme envisages the study of the effect of high winds on engineering structures, this relatively high starting speed is not going to affect the studies at all. Another limitation of

this equipment is with measurement of the duration of the gust speed at high winds. Even though the equipment takes up the gust speed rapidly, the speed may linger for a very short period beyond the actual duration of the gust. This if at all will only be advantageous for the studies of the effect of high winds on engineering structures as the data obtained would be more on the safe side and in any case the errors will be marginal.

For the temperature measurements a thermistor thermilinear component used as the seeing element inside a suitable weather shield with suitable electronic amplifier and a 0.1 mA strip chart recorder can be used. The sensor accuracy in the recorder is better than 0.5°C.

To equip 5 stations, three sets of equipment at each station we require 15 sets of equipment. Taking into account one set for each station as spare, a total of 20 sets of equipment have to be manufactured. The work involve procurement of number of items like Selsyn motors, multipole magnets, stampings, strip chart recorder, thermistor thermilinear components etc., from suppliers both in India and abroad, production testing, installation and maintenance. The items to be imported (thermistor thermilinear components) require a lead time of 12 to 18 months.

Cost of the equipment :

	<u>Quantity required</u>	<u>Amount in Rs. (lakhs)</u>
1) <u>Wind equipment</u>		
a) Sensors	20	1.5
b) Wind Panels	20	0.9
c) Twin Channel recorders	20	2.0
2) <u>Temperature Recorders</u>		
a) Sensors	20	0.2 (0.05)
b) Amplifiers	20	0.4
c) Single channel recorders	20	1.0
Total		6.0 (0.05)

Amounts given in brackets indicate the anticipated foreign exchange requirement in lakhs.

The sensors installed on the towers at three levels will have to be connected through shielded underground multicore cables (say 12 core cable) to the recorders and panels kept inside observatory rooms at a distance away from the tower any ½ km length of 12 core cable for each station.

Cost of Cable:

Amount in Rs.
(lakhs)

For 5 stations, 2½ Km. length of 12 core cable

0.65

Tower :

Since the towers for all the 5 stations are being provided by the Structural Engineering Research Centre, Madras, the cost of the tower is not included in the financial outlay given below.

4. Central Works :

About 250 metre by 100 metre plot is required for siting the towers and the observatory building. The plot must be completely fenced with a gate at a convenient point. The tower will have to be erected at one end of the site and the record rooms at another and about 150 m away from the tower. The observatory building should contain atleast two rooms each 5.5m dimensions with toilet and bath facilities with lights and fans and other electrical facilities. The recorders and panels would be kept in one room and the staff would use the other room for their regular evaluation, tabulation and computations work as well as for calibration purposes. Each building with fencing is estimated to cost about Rs. 2.0 lakhs.

5. Staff requirement:

Since the entire responsibility of production, testing, installation, maintenance and collection and tabulation of data rests with this office, it is envisaged that a small group of staff would be required in Pune I.S. and another small group in each field station. Procuring materials, liaison with the workshops, electrical wiring of the system after manufacturing in the workshop, testing and calibration of the equipment have to go on in the laboratory and then the instrument have to be installed at site. Therefore the staff proposed at Pune includes laboratory staff apart from workshop production staff:

Staff at Pune :

Meteorological Grade II	1
Professional Assistant	2
Mechanics Gr. I	4
Mazdoor	1

Status of Education on Wind Engineering

Information Received on Questionnaire on Teaching, Research
and Design Activities in the Area of Wind Engineering

-
- ACCT - A.C. College of Technology, Guindy, Madras
AEC - Assam Engineering College Library, Gauhati
BITS - Birla Institute of Technology and Science, Pilani, Rajasthan
CLA - College of Engineering, Amravati
CEG - College of Engineering, Goa
CEG(M) College of Engineering, Guindy, Madras
DCE - Delhi College of Engineering, Delhi
FTE - Faculty of Technology and Engineering, Vadodara
GSITS Shri G.S. Institute of Technology & Science, Indore
HKESEC H.K.E. Society's Engineering College, Gulbarga
IIT - Indian Institute of Technology, Kanpur
IRPE - Institute of Radio Physics and Electronics, Calcutta
MNREC Motilal Nehru Regional Engineering College, Allahabad
NEC - Nagarjunasagar Engineering College Saifabad, Hyderabad
REC - Regional Engineering College, Rourkela (Orissa)
SVRCET Sardar Vallabhbhai Regional College of Engineering & Technology, Surat (Gujarat)
TIET - Thapar Institute of Engineering & Technology, Patiala
URR - University of Roorkee, Roorkee
-

A. Teaching

1. Is any aspect of wind effects of structures, including
Is code provisions, covered as part of any course? Yes No
- A-1 i) AEC -Yes
 ii) URR -Yes

iii)	<u>GSITS</u>	-Yes
iv)	<u>CEA</u>	-Yes
v)	<u>CEG</u>	-Yes
vi)	<u>IIT</u>	-Yes
vii)	<u>TIET</u>	-Yes
viii)	<u>MNREC</u>	-Yes
ix)	<u>NEC</u>	-Yes
x)	<u>REC</u>	-Yes
xi)	<u>FTE</u>	-Yes
xii)	<u>CEG(M)</u>	-Yes
xiii)	<u>DEC</u>	-Yes
xiv)	<u>BITS</u>	-Yes
xv)	<u>IRPE</u>	-Yes
xvi)	<u>SVRCET</u>	-Yes
xvii)	<u>ACCT</u>	-No

If Yes, give details

If No, indicate future plans, if any

A-2 i) AEC - Consideration of W.L. as per IS:875-1964 is included in the course of Design of Structures. The students are guided to follow rigorously the relevant clauses of the code in their sessional work on Roof Truss Design and to check the W.L. against the Earthquake Load(as per IS:1893-1978) in their Multistoreyed Building Design Project.

ii) URR - Reference to wind load provisions is made in the course of Structural Design at final year level

iii) GSITS - Undergraduate level - Two compulsory papers and one elective paper dealing with design of Structures, include wind load analysis of various structures such as roof structures, multistoreyed framed structure, bankers and silos etc.

Post Graduate Level - One paper dealing with advanced structures analysis and one paper dealing with structural dynamics deal with wind load and earthquake load analysis for design purposes.

iv) HKESEC - In the undergraduate programme of teaching wind effects are taught in a cursory manner. There is no provision for detailed study of wind effect in structure.

v) CEA - a) A new curriculum "Energy Engineering" is proposed to be started, wind energy forms a sizeable portion of the Syllabi.

b) Projects will be assigned to final year students to design and develop wind turbine.

vi) CEG - IS:875-1964 is used in the design of steel and concrete structures, as part of the syllabus requirement of Civil Engineering Students.

vii) IIT - i) Department of Civil Engineering

I.S. Code provisions for wind loads are covered in the two undergraduate courses on Structural Design.

ii) Department of Aeronautical Engineering

Several aspects of Wind Engineering are covered under following courses:

AE - 563 Introduction to Industrial Aerodynamics (U.G). Scope of the subject; Motivation; Wind structure near the ground; Atmospheric boundary layer; Wind tunnel simulation and modelling; Wind forces on tall buildings and structures; Bluff body aerodynamics; Vehicle aerodynamics; Flow induced oscillations of suspension bridges, transmission lines, hydraulic structures, tubes; Architectural aerodynamics and effluent dispersal; Ventillation; Sheltering; Wind tunnels for industrial aerodynamics.

AE - 613 Wind Structure and Energy Extraction(P.G)

Characteristics of Earth's atmosphere. Terrain, Meteorological terminology. Turbulence in atmosphere and its nature. Measurement techniques of atmospheric turbulence and wind velocities. Atmospheric boundary layer. Mean profiles and similarity properties of wind speed.

Role of aerodynamics in wind power. Cross wind axis machines. Savonius rotor, Darrieus rotor. Wind axis machines. Ducted rotor, circulation controlled rotor. Smith Putnam design. Translating wind power machines. Wind axis rotors. General momentum theory, vortex strip theory, Cross wind axis machine. Some oretical modelling. Effects of the wind gradient.

Wind tunnel testing, including design of the models, instrumentation and data analysis is covered in the U.G. Course on Experimental Aerodynamics.

Stochastic formulation of wind effects on structures is covered in P.G. Course on Random Vibrations.

viii) TIET - High rise structures e.g. multistorey buildings, Transmission towers, Chimney's and sloping roofs are analysed for wind effects. Undergraduate and postgraduate students are introduced to the provisions of IS:875-1964 and IS:802 (Part I) - 1972 for designing such structures.

ix) MNREC - It is covered in the design of Buildings, Bridges and other structures with reference to IS:875 and IS:802.

x) NEC - We teach the design of tall buildings, elevated water towers etc in which the relevant provisions of the wind loads given in the IS: Codes (875-1964) are discussed and used.

xi) REC - In the following course offered;

Structural Design-II (Under Graduate)

Design of circular and rectangular water tanks, Design of roof trusses, purlins and stanchions (As per relevant IS: Codes).

Advanced Reinforced Concrete Design(Post Graduate)

Approximate wind analysis of building frames. Design of building frames, Water tanks and towers. (As per relevant codes of practice).

xii) FTC - i) At the undergraduate level, it is included in the subject of structural design and drawing covering the design of water towers, multistoreyed buildings, chimneys, etc.

ii) At the postgraduate level, in the subject of 'Design of Concrete Structures etc.', the IS Code provisions regarding wind analysis are taught while dealing with the design of multistorey building frames; chimneys, silos, bunkers, etc.

xiii) CEG(M) - a) Covered in the courses on "Design of Structures" offered for the undergraduate classes.

b) Covered as a separate course on 'Wind effects on Structures' for the Post-Graduate classes in Structural Engineering.

c) Covered as a part of the following courses offered for the Post-Graduate Classes in Structural Engineering.

- i) Reinforced Concrete Structures
- ii) Public Health Engineering Structures
- iii) Industrial Structures
- iv) Design of Prefabricated Structures

xiv) DCE - a) Use of IS:875 in the class work under Design of R.C.C. Structures.

b) In the design of Multistorey frames subjected of horizontal loads in Project work at under-graduate level.

xv) BITS - For the design of structures in the courses Analysis and design of Structures I and II, provisions of IS:875-1964 Code are taken into account.

xvi) IRPE - Wind effects on transmission line and antenna towers are covered in the Applied Mechanics course of our B.Tech. Part I syllabus.

xvii) SVR CET - a) Design of Structure - I
b) Design of Structure - II
c) Design of Structure - III
d) Elective - Metal Structure
e) Elective - Concrete Structures.

B. Research

1. List of M.Tech/Ph.D. Thesis completed in the area of Wind Engineering during the last five years

i) AEC - Nil.

ii) URR - Wind Response of Self Supporting Tall Towers, Ph.D. thesis by Mohd. Badruddin Ahmed, 1981.

iii) GSITS - Nil

iv) HKESEC- Nil.

v) CEA - Nil.

vi) CEG - Nil.

vii) IIT - Response of Launch Vehicles to Ground Wing, M.Tech. Thesis, 1973.

viii) TIET - M.E. Seminar of Aerodynamics - Stability of Structures.

ix) MNREC - Nil.

x) NEC - Nil.

xi) REC - Nil.

xii) FTE - Nil.

xiii) CEG (M)- M.E. Thesis

a) Dynamics Analysis of Tall Towers by Capt. Grewal 1976.

b) Wind effects on Transmission Line Towers by Jayasekaran 1977.

- c) Cyclone loads on Power House Structures
by K.B. Singh 1979.

Ph.D. Thesis

- a) 'Wind loads on Transmission line Towers'
by R. Rangaswamy - 1979.

- xiv) DCE - M.Sc.(Engg) Thesis on ANALYSIS OF TALL BUILDINGS
WITH AXIAL DEFORMATIONS.

Guides - Dr. H.S. Ramaswamy and Shri K.V. John, Year 1979.

- xv) BITS - Nil.

- xvi) IRPE - Nil

- xvii) SVRCET - Nil.

- xviii) ACCT - Nil.

B-2. List of Publications in the Area of Wind Engineering during
the last Five Years.

- i) AEC - Nil.

- ii) URR - 1. 'Failure of A.I.R. Transmission Towers due to
Delhi Tornado, March 1978', Jnl. Inst., of Engrs., India, 1979

2. 'Effect of Cyclones on Structures' with
reference to Vishakhapatnam Steel Plant. Research Report.

- iii) GSITS - Nil.

- iv) HKESEC - Nil.

v) CEA - Design aspects and performance of wind turbine
operated Electric generators' - By M.S. Deshpande and
Dr. S.S. Pingle, Seminar on Appropriate Technology for
rural development, Institution of Engineers (I), U.P.
State Lucknow, 9-11 Jan. 1981.

- vi) CEG - A winter school on "Design and construction of
off-shore structures" was conducted by the Civil Engineering
Department during December 79 - January 80. During this
winter school lectures were delivered on "Wind and Wind
loading."

- vii) IIT - Nigam N.C., Gupta A.K., and Mathur S.P., "Wind
Tunnel Study and Probabilities Dynamic Analysis of a Pylon
For Wind Loading", Seminar on Industrial Aerodynamics,
Feb. 8-10, Institution of Engineers, India (To appear in
in the J. of Institution of Engineers).

- viii) TIET - Nil.
- ix) MNREC- Nil.
- x) NEC - Nil.
- xi) REC - Nil.
- xii) FTE - Nil.
- xiii) CEG(M) - i) M. Lakshmipathy and Dr. A.R. Santhakumar(1980), Use of Reinforced Fibrous Concrete for Disaster Prone Areas, Proceedings of International Conference on Engineering for Protection from Natural Disaster, AIT, Bangkok.
- ii) A.R. Santhakumar, J. Sivakumar, A. Swamidurai (1980), Behaviour of Joints in Prefabricated Shear Walls for Seismic Zones, Proceedings of
- iii) N. Chitharanjan, A.R. Santhakumar (1980), Use of Light weight Aggregate Concrete from waste products for seismic zones, Proceedings of
- iv) Dr. A.R. Santhakumar et al (1980), Engineered Anti-Disaster Measures of the state of Tamilnadu (India), Proceedings of
- v) J. Mohan (1980), Land slide - Disaster Planning- Analysis with a case study, Proceedings of
- vi) A.R. Santhakumar 'Wind Induced Oscillations of Transmission line Towers' Journal of Structural Engineering CSIR - SERC Roorkee - (1979).
- vii) A.R. Santhakumar 'Collapse of Power House Structure during 1977 cyclone at Vijayawada' Journal of Tor steel foundation, Accepted for publication.
- xiv) BITS - Nil.
- xv) IRPE - Nil.
- xvi) SVRCET - Nil.
- xvii) ACCT - Nil.

List of the names of faculty members interested in the area of Wind Engineering

- i) AEC - Dr. N.K. Chaudhury,
Professor, Civil Engineering.
- ii) URR - Dr. Prem Krishna
Dr. P.K. Pande
Sri G.L. Asawa
Dr. A.K. Jain

- iii) GSITS - 1. Prof. M.R. Mahajan, Reader in App. Mech.
2. Prof. R.U. Sachar, Reader in App. Mech.
- iv) HKESEC - None.
- v) CEA - 1. Prof. Dr. S.S. Pingle I/c Principal College of Engineering, Amravati.
2. Prof. Dr. M.G. Deshpande, Asstt. Prof. of Mech Engg. College of Engineering, Amravati.
- vi) CEG - Dr. S.V. Ramachandran, Assistant Professor in Applied Mechanics, College of Engineering, Farmagudi - Goa.
- vii) IIT - 1. Dr. M.P. Kapoor, Professor in Civil Engineering.
2. Dr. P. Dayaratnam, Professor in Civil Engineering.
3. Dr. A.K. Gupta, Professor in Aero. Engg.
4. Dr. A.C. Jain, Professor in Aero. Engg.
5. Dr. K. Ghosh, Asstt. Prof. in Aero. Engg.
6. Dr. N.C. Nigam, Professor in Aero. Engg.
- viii) TIET - 1. Prof. V.V. Sastry
2. Prof. C.B. Rupreja
3. Prof. Amarjeet Juneja
4. Prof. S.N. Bhalla
5. Dr. M.L. Gambhir
- ix) MNREC - Dr. Y.P. Gupta, Professor, Civil Engineering Department MNR Engineering College, Allahabad.
Mr. Jai Prakash, Lecturer -do-
- x) NEC - 1. Dr. R. Nagaraja, Professor & Head, Deptt. of Civil Engg. Jawaharlal Nehru Technological University, Engineering College, Hyderabad-500 438.
2. Sri B.L.P. Swamy, Lecturer
3. Sri A.K. Asthana, Lecturer
- xi) FTE - 1. Dr. V.S. Thaltay
2. Dr. S.C. Patodi.
- xii) CEG (M) - Dr. P. Purushothaman
Dr. A.R. Santhakumar
- xiii) DCE - 1. Dr. H.S. Ramaswamy
2. Shri K.V. John.
- xiv) BITS - Dr. A.C. Mathai, Assoc. Prof. in Civil Engg.
Shri H.S. Moondra, Asst. Prof. in Civil Engg.
- xv) IRPE - None.
- xvi) SVRCET - 1. Dr. D.A. Inamdar
2. Prof. B.S. Bulsari

3. Prof. B.M. Raval
4. Shri B.R. Patel
5. Shri B.R. Patel
6. Shri D.B. Raijiwala
7. Shri V.M. Inamdar
8. Shri H.S. Patil

xvii) ACCT - Nil

Design

List of Design of Projects completed in the area of Wind Engineering during the last five years

- i) URR - Nil.
- ii) GSITS - Nil.
- iii) HKESEC - Nil
- iv) CEA - Nil.
- v) CEG - Nil.
- vi) IIT - i) Design of a Pylon against Wind at Mahatma Gandhi Institute, Mauritius.
 ii) Dynamic Analysis of Masts against Wind at Delhi Airport.
 iii) Static and Dynamic Analysis of several T.V. Towers (300 m, 100 m).
 iv) Design of a large antenna network against wind.
- vii) TIET - Nil.
- viii) MNREC - Design of Hi-rise Buildings.
- ix) NEC - 1. Design of a 10 storey office complex.
 2. Design of Several Industrial buildings.
- x) FTE - Design of multistorey buildings and water towers as part of submission work (Term-work) done by the students of M.E. (Structures) Course.
- xi) CEG(M) - i) Wind load Paraboloidal Antennas for M/s Helix Antenna
 ii) Wind load on Industrial Structures ~~Loads~~ on sheet roof.

iii) Wind load effects on Braced Domes.

iv) Wind effects on 26 storey Towers at Bamkalapatia Sri Lanka for M/s. Engineering Construction Company

v) Wind effects on 10 storied Hausing Board Buildings, Government of Tamilnadu.

vi) Wind effects on Multistoried Water Board Buildings, Government of Tamilnadu.

vii) Wind effects on 'Storey Port trust building Hausing a Cyclone tracking radar in a Radome for Port Trust, Madras.

xii) DCE - Projects of Final Year under-graduate students on the Design of Tall buildings for the last Five-years except during 1979-80

xiii) BITS- Nil.

xiv) IRPE- Nil.

xv) SVRCET - Nil.

xvi) ACCT - Nil.

D. ANY OTHER INFORMATION

i) URR - 1. The work at B. 1 has been completed with the assistance of a research scheme sponsored by Indian National Science Academy.

2. A research scheme entitled 'Effect of Subsonic Winds on Civil Engineering Structures' has been sponsored by the Department of Science and Technology.

A wind tunnel with a 2 m x 2 m section with a 15 m test section is under construction and is due to be functional this year (1981). The tunnel is designed for industrial testing.

Two Ph.D. Scholars are pursuing research in the area of Wind Engineering.

ii) GSITS ~ In collaboration with National Aeronautical Laboratory Bangalore, three wind mills are to be set up in the locations near by Indore. These will be fabricated, Installed and studied for performance characteristics by this Institute. The analysis and design of the towers and foundations for the mills has been entrusted to Prof. M.R. Mahajan of this Institute.

iii) HKESEC - Nil

iv) CEA - Pilot Project for optimization of wind turbine is being assigned to final year Mech/Elect. Students during 1981-82.

v) CEG - The National Institute of Oceanography may be contacted to obtain useful information on this topic.

vi) MNREC - i) Project on Analysis for Static and Dynamic Effect of wind on Transmission and Lighting towers.

ii) Project on Analysis for forces in tall guyed Mast (Single and Multiple) for Static and Dynamic effects.

vii) FTE - Nil.

viii) CEG(M) - i) Staff listed in C are serving as members of the cyclone Havoc mitigation committee constituted by Government of Tamilnadu.

ii) The department has conducted winter school on 'Wind Force on Structures' sponsored by ISTE. Co-ordinator - Dr. A.R. Santhakumar.

iii) A.C.S.I.R. sponsored project on 'Optimum design of Transmission line Towers' had been completed in which with effects had been studied. Principal Investigator - Dr. A.R. Santhakumar/Mr. A. Swami Durai.

iv) ACSIR sponsored project on 'Wind effects on Prefabricated shear walls' was completed. Principal Investigator - Dr. A.R. Santhakumar/Mr. A. Swami Durai.

v) AUGS sponsored project on 'Cyclone working Device for Rural Areas' is under progress. Principal Investigator- Dr. A.R. Santhakumar.

vi) A Project sponsored by Government of Tamil Nadu on 'Cyclone Warning Device' is under progress, Principal Investigator- Dr. A.R. Santhakumar.

vii) A Project on 'Wind Induced Oscillations for cyclone shelters' sponsored by Directorate of Town and Country Planning is in progress, Principal Investigator- Dr. A.R. Santhakumar,

ix) BITS - Nil.

x) SVR CET - Nil.

xi) ACCT - Nil.

The following Institutions have sent the information Nil with reference to the above questionnaire:

- 1) College of Engineering Karad (Distt.Satara)
- 2) Coimbatore Institute of Technology, Coimbatore
- 3) D.E.I. Engineering College, Dayalbagh, Agra.



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